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Contents

Global overview of unmanned aerial vehicles research: country-level and organisation-level bibliometric analysis

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Abstract

This study proposes the global bibliometric overview of unmanned aerial vehicles (UAVs) research in Scopus database in 1985 – 2015. This study detects key countries in this field of research as well as the major centers of excellence (organisations) in UAV research. We analyse publication activity of leading countries and organisations as well as the level of citation of their UAV publications. Special section is devoted to the analysis of cross-country collaboration links. For plotting the map of international collaboration in UAV research, VOSviewer software was used.

Keywords: Unmanned aerial vehicles; UAV; aviation; publication activity; Scopus; VOSviewer; bibliometric analysis; international collaboration; citation analysis; scientometrics.

Conference Topic:
Journals, databases and electronic publications
Country-level studies
Mapping and visualization

Introduction

Unmanned aerial vehicles (UAVs) become a new special sector on aviation industry. The application of unmanned aerial vehicles is widespread: from giant global Hawk to micro aerial vehicles used in precise agriculture. Unmanned aerial vehicles research is related with many different fields of science. First there are spheres of research directly related with aviation science. UAV research posts new questions in fields of aerodynamics. The key questions here is how to measure, control and improve the aerodynamic characteristics on UAVs of untraditional forms: flying wing, spherical UAVs, UAVs with flexible and flapping wings, insect-like UAVs, quadricopters, etc.[1]. Principally new avionics is needed for UAVs. In avionics for UAVs the key role plays artificial intelligence controlled avionics or avionics system that are remotely controlled by human[2]. New paradigm of flight management systems (FMS) is needed[3] . With the fast development of unmanned aerial vehicles industry the new challenges for aviation safety (primarily related with antiterrorist control) arise[4]. UAVs also change the essence of military aviation[5].

It should be said that there was only several examples of bibliometric analysis of research in the field of aviation and aerospace industry:

- Studies devoted to the bibliometric analysis of aerospace and aeronautical journals (Meskoob and Tanbakouei, 2012; Nageswara Rao et al. 2014; Aswathy and Pal, 2015);
- General bibliometric analysis of specific subfields of aerospace science (Ganguli, 2008; Evans, et al. 2008, 2009; Rezadad & Maghami, 2014; Rojas-Sola and Aguilera-García, 2014)
- Technological mining in specific subfields of aerospace science based on bibliometric and patent analysis (Nakamura et al., 2010, 2012; Xu and Hua, 2014; Li and Guo; 2015).
- Analysis of publication activity in some organizations (and its divisions) related with aerospace research (Stephens, 2013; Nakamura, Kajikawa, and Suzuki; 2014).

This paper is among the first studies that provide the global overview of publication activity in field of unmanned aerial vehicles. This study detects key countries and key centers of excellence in this field.

1. Methodological issues

To run the bibliometric analysis on unmanned aerial vehicles (UAV) it is needed first to determine the field of search for these publications. Two greatest multisubject science citation databases that are recognized by the international scientific community and have well-developed interface for a bibliometric analysis are Scopus and Web of Science. These databases among other possibilities for bibliometric analysis allow the user to search any term (as well as combination of terms) in tittle, abstract and keywords of publications. In this paper, Scopus database was used since Web of Science database does not have the system of unique author identifiers and unique organization identifiers. Therefore, the possibilities for the analysis of publication activity of individual organizations and authors in Web of Science are seriously

[1] The various aspects of research on the aerodynamic characteristics of unmanned aerial vehicles are studied in e.g. Ansari et al., Curet et al., 2013.

[2] Some examples of research on avionics in application to unmanned aerial vehicles are e.g. Naruoka et al. 2009; Sudha Rani and Ramadoss, 2015

[3] Examples of studies on flight management systems within UAV research are: Koo et al., 1999; Pasaoglu et al., 2016.

[4] Discussion on problems of hacking and hostile takeover of UAV control can be found in: Kim et al., 2012; Dulo, 2015.

[5] Examples of studies on military application of UAVs are: Tozer at al., 2000; Gowtham and Gnanasundari, 2015.

constrained in contrast to Scopus[6]. Moreover, in Scopus the number of publications on unmanned aerial vehicles in different periods is 1.5 – 3.5 times higher than in Web of Science.

To detect publications on UAVs the search in title or abstract or keywords of publications was done the following terms (and all forms of them): unmanned aerial vehicle; unmanned airborne vehicle; unmanned flying vehicle; pilotless aerial vehicle; pilotless flying vehicle; unmanned aircraft; pilotless aircraft; unmanned helicopter; pilotless helicopter; unmanned copter; pilotless copter; unmanned plane; pilotless plane; unmanned drone; pilotless drone; air drone; aerial drone; flying drone; quadrocopter; quadricopter; micro aerial vehicle, micro air vehicle; micro flying vehicle; micro aircraft system. Such abbreviations like UAV, UAVs, MAV MUAV etc. were not included into the search query in order not to take irrelevant words like "User Antenna View"; "Mars Ascent Vehicle", "Modular Acoustic Velocity Sensor" etc. We should understand: when we search for the word "unmanned Ariel vehicle" in title, abstract or keywords of the publication we take into our analysis not only publications devoted directly to unmanned aerial vehicles but also publications where the word combination "unmanned aerial vehicle" is simply mentioned. On the other hand mentioning UAV-related term(-s) in abstract or keywords of a given publication means that this publication is at least indirectly related with unmanned aerial vehicles. Moreover, the search only in the title of publications is a very narrow approach. In many cases author may not mention the word "unmanned aerial vehicles" in the title when the publication is devoted to use of some material or some technologies in unmanned aerial vehicles or new ways of application of UAVs. Therefore, in our case we treat all publications where the above mentioned UAV search terms are mentioned in title or keywords or abstract as publications related with unmanned aerial vehicles. All types of documents and all types of sources were included in the analysis.

2. Country-level analysis of publication activity in UAV studies

Since more or less stable dynamics of publications in Scopus database starts since 1985, we analyse the dynamics of publication activity on UAVs for the period of 1985 – 2015. There were several periods of rapid growth of global number of UAV publications in Scopus: 2001 – 2007 and 2012 – 2013.

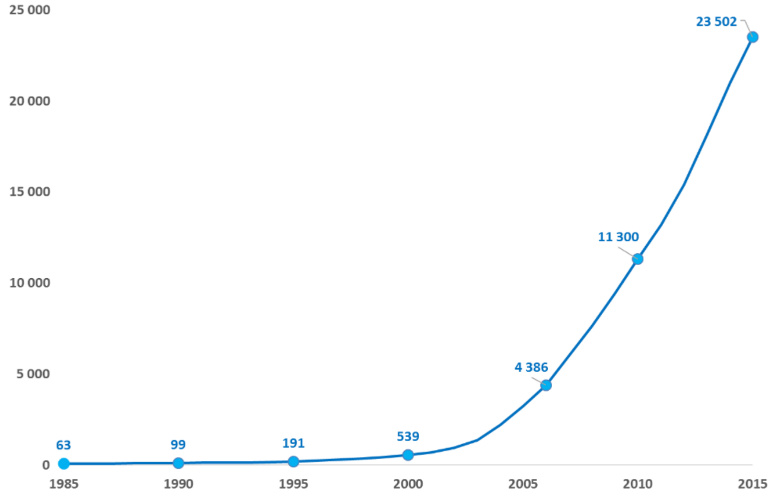

Figure 1. Evolution of unmanned aerial vehicles research in Scopus in 1985 – 2015.

Notes: All types of documents and sources indexed in Scopus are included in the analysis. The analysis was done in 2nd decade of January 2016.

[6] See more on advantages and limitations of Scopus vs. Web of Science in e.g. Meho and Yang, 2006; Falagas et al, 2008; Archambault et al., 2009; Vieira and Gomes, 2009; Shashnov and Kotsemir, 2015.

The United States is the major player in global UAV studies (Figure 2). For 1985 – 2015 USA contributed 35.8% of global come of publications on UAVs. The other big player is China whose contribution for 1985 – 2015 was 20.4%. The rocket growth of publication activity in UAVs in China started in 2005. The share of China in global volume of publications on UAVs has increased from 4.9% in 2002 to 26.5% in 2015[7]. The share of the United States on the contrary decreased from 68.8% in 2000 to 23.7% in 2015 (Table A.1). The contribution of any other country into global volume of publications in UAVs was less than 5% for 1985 – 2015. In the Europe the leaders on number of publications are Western European countries – UK with 935 publications on UAVs for 1985 – 2015 (4.5% of global volume of publications), Germany with 872 publications (4.2%) and to a less extent France with 724 publications (3.5%). Among Eastern European countries the leader is Poland with 227 publications for 1985 – 2015 (1.1 % of contribution into global volume of publications). It is followed by the Russian Federation (169 publications, 0.8%), Czech Republic (116 publications, 0.6%) and Ukraine (99 publications). In South America the leader is Brazil with 286 publications (1.4% global volume of publications) on UAVs for 1985 – 2015. It is followed by Argentina with 37 Publications. In Africa the leaders are Algeria – 67 publications on UAVs (0.3% of global volume of publications) and South Africa – 57 publications. In Asia the other important players (in addition to China) in UAV research are South Korea with 794 publications for 1985 – 2015 (3.9% of global volume of publications) and Japan with 603 publications (2.9%).

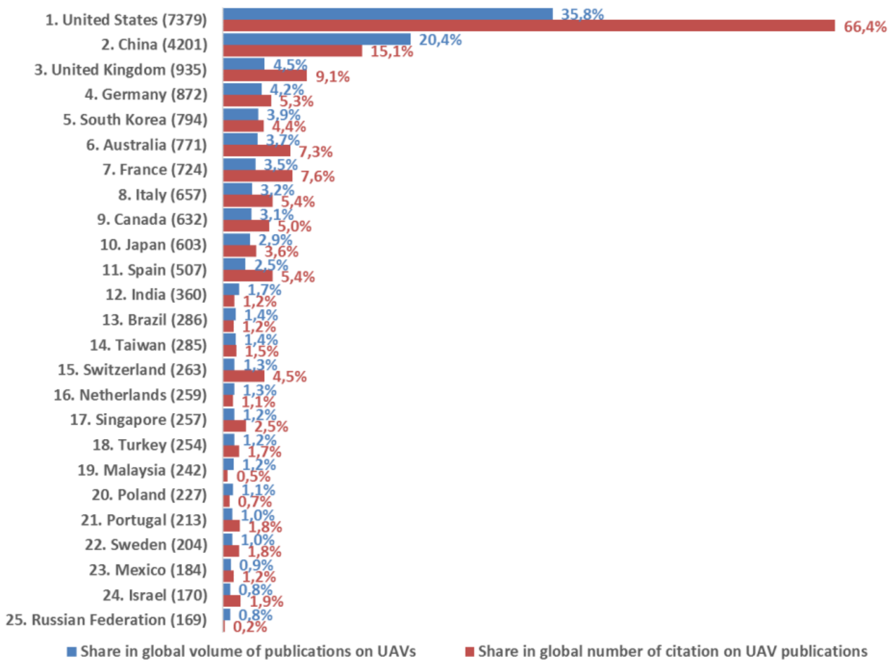

Figure 2. Key countries in UAV research in Scopus in 1985 – 2015

Notes: All types of documents and sources indexed in Scopus are included in the analysis. The analysis was done in 2nd decade of January 2016.

World average level of citations of UAV publications for 1985 – 2015 is 3.29 citations per one publication. In terms of citations on UAV publications, the domination of the USA was much higher than in terms of publication activity. USA received 66.4% of all citations on UAV publications. The average level of citation of publications of the USA is 6.10 cites per document. China received 15.1% of world volume of publications, while UK 9.1%. Meanwhile in China the level of citation was much lower than in the USA – only 2.43 cites per document. In general, countries with the highest level of citations per one UAV publication have low level

[7] Such a situation of the rocket growth of publication activity in China can be seen not only in UAVs studies but also in many other fields of science (see Kotsemir 2012a, 2012b).

of self-citation and quite high level of integration in international scientific collaboration (Figure 3).

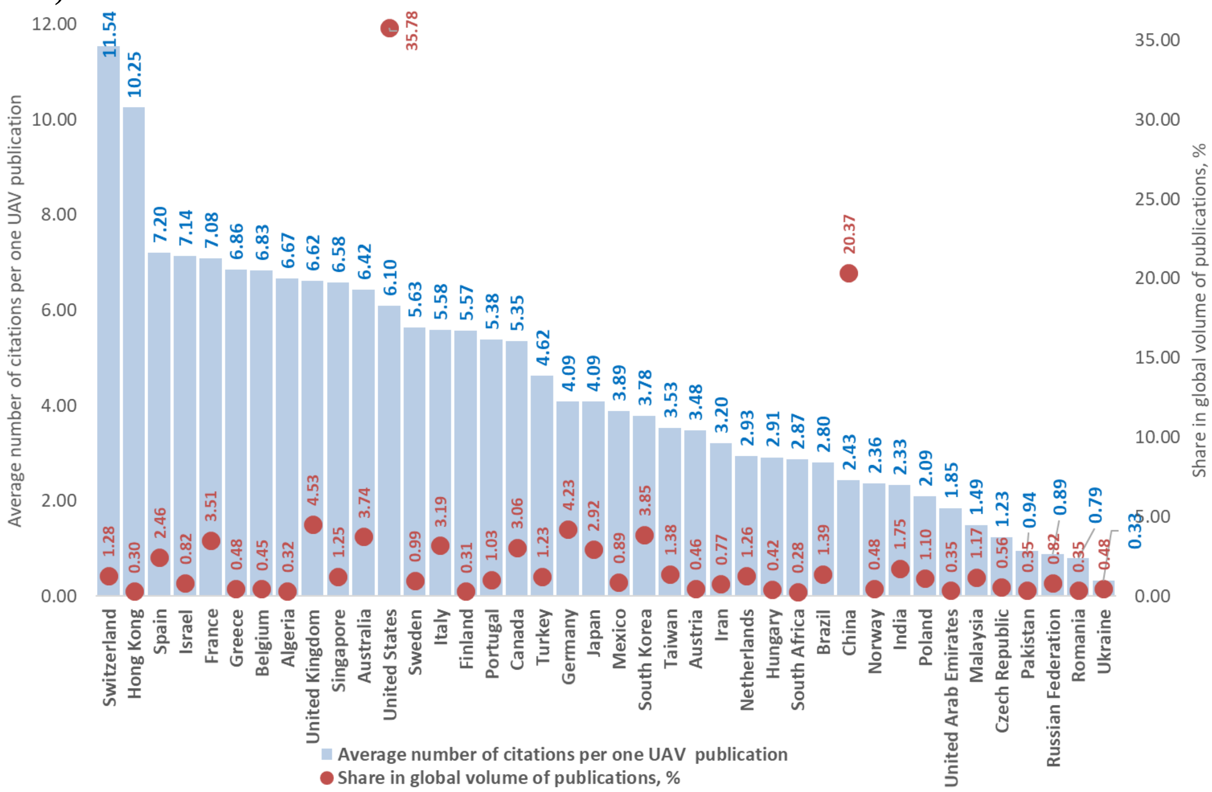

Figure 3. Countries with the highest level of average citation in unmanned aerial vehicle research

Notes: All types of documents and sources indexed in Scopus are included in the analysis. The analysis was done in 2nd decade of January 2016.

The highest level of citation per one publication (“cites per doc” further) has Switzerland: 11.24. In Hong Kong the value of this indicator was also very high: 10.25 cites per doc. Among countries with more than 50 publications on UAVs in Scopus for 1985 – 2015 the lowest “cites per doc” ratio has Ukraine – only 0.33 citations per publication. In some countries cites per doc ratio was lower than 1.00: Romania (0.79), Russian Federation (0.89) and Pakistan (0.94)[8]. In general, Western European countries have the highest level of citation per publication among macro-regions[9]. In the Asian region the highest level of cites per doc have countries with quite small number of UAV publications. It is already mentioned Hong Kong (with 10.25 “sites per doc” value; 61 publications) and to a lesser extent Israel (7.14; 170) and Singapore (6.58; 257). For comparison China, the second major player in UAV research with 4201 publications, has only 2.43 citations per one publication in average. Other Asian countries with big number of UAVs publications have low value of “cites per doc” indicator: Republic of Korea (3.78 with 794 publications); Japan (4.09 with 603 publications). Russia and Ukraine have the highest level of self-citation among countries with 50 and more publications on UAVs. 49.7% of publications of Russia on UAVs was cited by authors of these publications. For Ukraine this figure is 44.7%. Quite high share of self-citation has Finland (34.0%) (see Table A.2 for details).

[8] The problem of very low relative levels of citation in Russia, low level of citation in Asia vs. Europe, very high level of citation in Switzerland can also be seen for the total volume of publications both in Scopus and Web of Science databases (see Kotsemir 2012a, Kotsemir 2012b).

[9] This phenomenon can be seen for the total number of publications (see Kotsemir 2012a, Kotsemir 2012b).

3. International collaboration in unmanned aerial vehicle research

Figure 4 depicts the map of cross-country collaborations in unmanned aerial vehicle research in Scopus for 2000 – 2015. This map was plotted using VOSviewer software[10]. The dominance of the United States and China is clearly seen on this map. The United States can be treated as metaintegrator on this co-authorship map due to its dominating role in UAVs research.

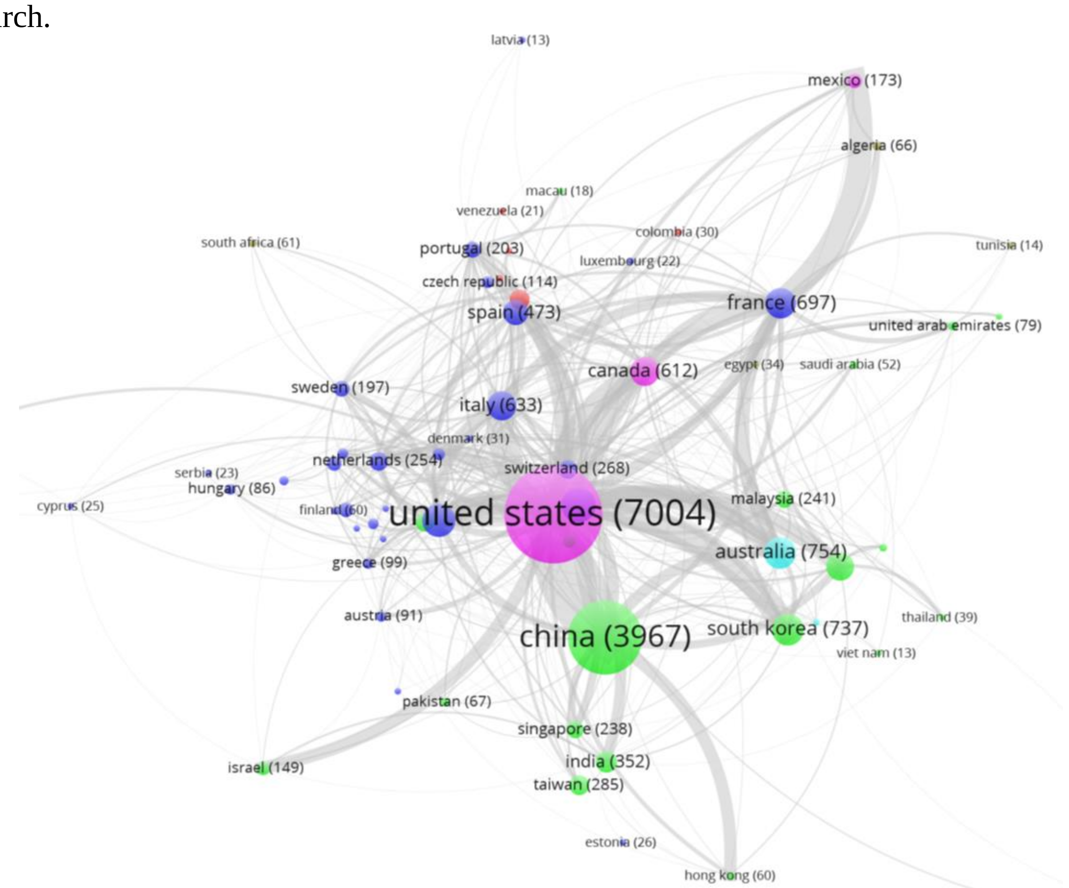

Figure 4. Collaboration map of countries in the field of unmanned aerial vehicle studies in Scopus for 2000 – 2015, coloring based on geographical location

Notes: All types of documents and sources indexed in Scopus are included in the analysis. The analysis was done in 2nd decade of January 2016. Country statistics is taken through proceeding Countries are colored based on geographical location: **Green bubbles – Asia**; **Blue – Oceania**; **Magenta (dark pink) – North America**; **Violet – Europe**; **Olive – Africa**; **Orange – South America**

We also can see other key players on this map such as UK, Australia, Japan, South Korea, France, Germany, Italy and Brazil. There are two clusters of collaboration: Asian cluster with the dominance of China, South Korea and Japan European cluster, where key nodes are Italy, Spain, Germany, and France. Australia is included into intercontinental collaboration: cooperation with UK, France, USA, Canada, South Korea and China have high importance for Australia. It should be noted nevertheless that Asian partners for Australia are far less important for Australia than European and North American ones.

[10] According to description from it official website: "VOSviewer is a software tool for constructing and visualizing bibliometric networks. These networks may for instance include journals, researchers, or individual publications, and they can be constructed based on co-citation, bibliographic coupling, or co-authorship relations". VOSviewer also offers text mining functionality that can be used to construct and visualize co-occurrence networks of important terms extracted from a body of scientific literature". Its names VOSviewer takes from (**V**isualization **O**f **S**imilarities **viewer**). See more on http://www.vosviewer.com .

China with 3299 publications on unmanned aerial vehicles in Scopus in 2000-2015[11] has only 354 co-authorship links. China takes here "publish or perish" strategy. Chinese authors are publishing very actively in the field of unmanned aerial vehicles primarily with each other without active (in comparison to the whole volume of publications on UAVs) integration into international scientific collaboration. Other leading Asian countries in UAV research also have low share of integration in international collaboration. India has 77 co-authorship links per 303 publications Republic of Korea has 174 co-authorship links per 646 publications. In leading European countries the level of integration into international scientific collaboration is much higher, than un Asia. United Kingdom has 353 co-authorship links per 786 publications, Germany – 317 co-authorship links per 742 publications, France – 408 co-authorship links per 629 publications.

4. Key organisation in UAV studies

The analysis of publication activity for organisations[12] with the biggest number of UAVs publication is synthesized in Table A.3. US and Chinese organisations hit global ranking of centers of excellence on absolute number of UAV publications (Figure 5).

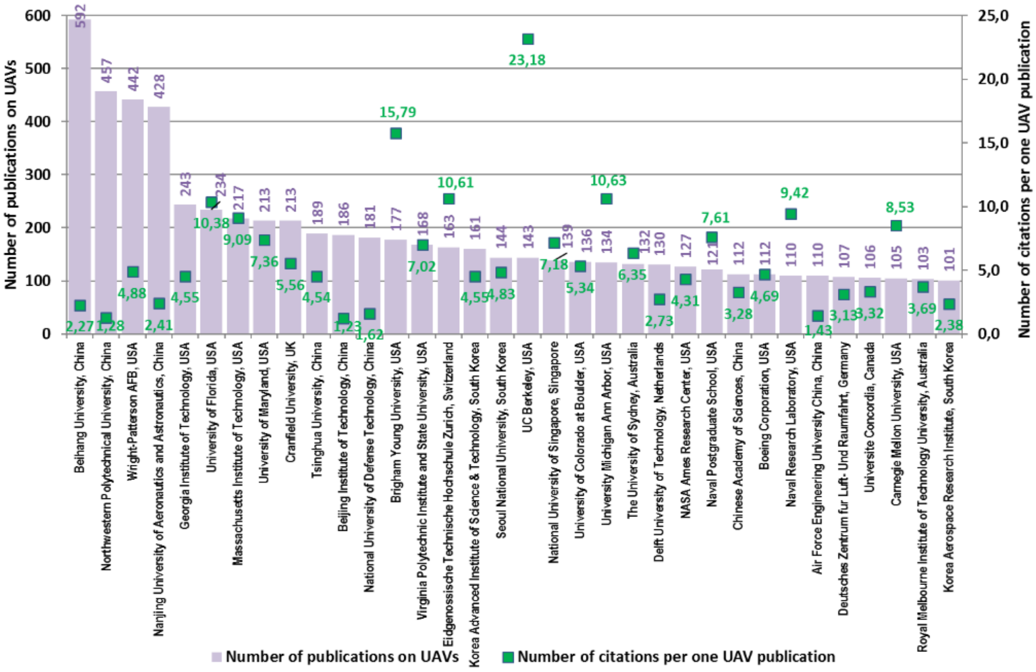

Figure 5. Key centers of excellence on UAVs research in Scopus in 1985 – 2015.

Notes: All types of documents and sources indexed in Scopus are included in the analysis. The analysis was done in 2nd decade of January 2016.

The most productive organisation in UAVs studies in Scopus in 1985 – 2015 is Northwestern Polytechnical University (China, Xi'an) with 592 publications (14.1% of contribution into total number of Chinese publications). It is followed by: Northwestern Polytechnical University (China, Xi'an) with 457 publications on UAVs (10.9% of contribution into total number

[11] Since VOSviewer detects country names from bibliographical descriptions of publications more accurately than Scopus automatic affiliation matching mechanisms the number of publications for each country after proceeding their descriptions trough VOSviewer software is higher than when user takes country data directly from Scopus database.

[12] We should note here that due to inaccurate indexation of organisation affiliation name by Scopus search engine some publications of a given organization are not linked with this organization automatically. This problem is more serious in non-English speaking countries (see Kotsemir and Shashnov, 2015 on more details on this problem). In other words, Northwestern Polytechnical University (China, Xi'an) in fact has more than 457 publication on UAVs in Scopus for 1985 – 2015.

of Chinese publications); Wright-Patterson AFB (Air Forces Base) (USA, Dayton) with 442 publications (6.0% of contribution into total number of US publications); Nanjing University of Aeronautics and Astronautics (China, Nanjing) with 428 publications (10.2% of contribution into total number of US publications). The highest level of citations per one UAV publication among organisations with 75 and more UAV publications for 1985 – 2015 have UC (University of California) in Berkeley (USA, Berkeley): 23.2 cites per doc and University of Pennsylvania (USA, Philadelphia): 22.7 cites per doc.

Chinese organisations dominate in the global ranking of organisations on number of publications on UAVs. Meanwhile, they have low level of citations (Figure 5). This figure also show that among the top countries on UAVs studies US organisations have in general higher level of citations per one publication. Table A.3 also helps to detect the key national centers of excellence in UAV studies. E.g. in Switzerland 62.0% of national volume of UAVs publications was done by Eidgenossische Technische Hochschule Zurich (163 publications on UAVs for 1985 – 2015). In Singapore the main national centres of excellence on UAV studies are National University of Singapore (54.1% of contribution into national volume of UAV publications) and National Cheng Kung University (34.2%) (Table A.3). Linkopings Universitet with 90 publications contributed 44.1% of the total number of UAV publications in Sweden.

5. General findings and conclusions

This paper proposed the bibliometric overview of unmanned aerial vehicle research in different countries. The analysis shows the strong domination of the USA in terms of publication activity and number of citations received. Meanwhile we can see the growing importance of China in the last years. By 2015 China became the second greatest country in UAV research. Meanwhile in terms of citations European countries as well as USA and Canada take the leadership while Asian countries (expect of small countries like Singapore and Hong Kong) lags behind the leaders. On the level of organisations the US and Chinese organisation are the most productive in UAV research. Meanwhile leading Chinese organisations have much smaller number of citations per one publication than their “competitors” from the USA, Canada and Western Europe.

Several possible directions of further research can be proposed. One of the possible ways for development of this research is a more detailed analysis of international collaboration in UAV studies with focus on individual organisations. The other potential development of this research is running the semantic analysis. Using VOSviewer or the other similar software, we can derive different terms from titles, keywords and abstracts of publications on unmanned aerial vehicles. Further using the algorithms of natural language processing and cluster analysis based on co-occurrences of terms and words in titles, abstracts and keywords of UAV publications most important topics of UAV research can be detected.

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Appendix

Table A.1. Dynamics of publication activity on UAVs research in the 25 leading countries on number of publications on UAVs in Scopus in 1985 – 2015

№	Country	Number of publications in Scopus								Share in the global volume of publications in Scopus, %							
		1985	1990	1995	2000	2005	2010	2015	1985-2015	1985	1990	1995	2000	2005	2010	2015	1985-2015
1	United States	1	2	11	66	443	619	577	7379	50.0	50.0	42.3	68.8	61.5	35.9	23.7	35.8
2	China			2		93	360	646	4201			7.7		12.9	20.9	26.5	20.4
3	United Kingdom			3	5	37	88	104	935			11.5	5.2	5.1	5.1	4.3	4.5
4	Germany				2	12	76	90	872				2.1	1.7	4.4	3.7	4.2
5	South Korea					23	62	92	794					3.2	3.6	3.8	3.9
6	Australia				5	26	47	82	771				5.2	3.6	2.7	3.4	3.7
7	France	1		1		24	41	90	724	50.0		3.8		3.3	2.4	3.7	3.5
8	Italy				3	8	43	107	657				3.1	1.1	2.5	4.4	3.2
9	Canada		1	2	3	16	58	91	632		25.0	7.7	3.1	2.2	3.4	3.7	3.1
10	Japan			3	3	21	73	46	603			11.5	3.1	2.9	4.2	1.9	2.9
11	Spain					3	35	96	507					0.4	2.0	3.9	2.5
12	India					10	29	57	360					1.4	1.7	2.3	1.7
13	Brazil			1		1	27	50	286			3.8		0.1	1.6	2.1	1.4
14	Taiwan					4	30	25	285					0.6	1.7	1.0	1.4
15	Switzerland				2	4	27	41	263				2.1	0.6	1.6	1.7	1.3
16	Netherlands		1		2	4	17	49	259		25.0		2.1	0.6	1.0	2.0	1.3
17	Singapore						36	22	257						2.1	0.9	1.2
18	Turkey					2	21	38	254					0.3	1.2	1.6	1.2
19	Malaysia						20	37	242						1.2	1.5	1.2
20	Poland				1	8	9	28	227				1.0	1.1	0.5	1.2	1.1
21	Portugal			1		5	16	40	213			3.8		0.7	0.9	1.6	1.0
22	Sweden				2	7	29	11	204				2.1	1.0	1.7	0.5	1.0
23	Mexico					3	3	28	184					0.4	0.2	1.2	0.9
24	Israel	1		2	3	8	12	20	170	50.0		7.7	3.1	1.1	0.7	0.8	0.8
25	Russian Federation					4	10	46	169					0.6	0.6	1.9	0.8

Notes: All types of documents and sources indexed in Scopus are included in the analysis. The analysis was done in 2nd decade of January 2016.

Table A.2. Key indicators of publication activity on UAVs in leading countries in 1985-2015

	Absolute number of publications	Share in global volume of publications, %	Average number of citations per one publication (cites per doc)	Share of self citation, %	Share of never-cited publications, %	Number of internationally collaborated publications (ICP)	Share of Internationally collaborated publications (ICP), %	Cites per doc for ICP	Cites per doc ICP/cites per doc for purely national publications
United States	7379	35.8	6.10	13.6	53.5	1 050	14.2	9.44	1.70
China	4201	20.4	2.43	18.2	55.5	410	9.8	5.44	2.58
United Kingdom	935	4.5	6.62	16.6	47.6	345	36.9	7.12	1.12
Germany	872	4.2	4.09	23.6	47.8	267	30.6	5.91	1.80
South Korea	794	3.9	3.78	21.7	50.3	180	22.7	6.36	2.11
Australia	771	3.7	6.42	14.5	45.3	253	32.8	9.98	2.13
France	724	3.5	7.08	16.2	47.8	352	48.6	8.13	1.33
Italy	657	3.2	5.58	24.9	44.7	213	32.4	7.64	1.66
Canada	632	3.1	5.35	17.1	46.5	210	33.2	7.21	1.63
Japan	603	2.9	4.09	17.6	56.6	136	22.6	8.87	3.29
Spain	507	2.5	7.20	21.8	42.0	171	33.7	5.97	0.76
India	360	1.7	2.33	15.7	66.9	79	21.9	4.66	2.78
Brazil	286	1.4	2.80	26.3	63.6	101	35.3	5.51	4.16
Taiwan	285	1.4	3.53	20.2	53.7	30	10.5	4.00	1.15
Switzerland	263	1.3	11.54	13.3	33.8	100	38.0	10.37	0.85
Netherlands	259	1.3	2.93	25.8	54.1	127	49.0	3.11	1.12
Singapore	257	1.2	6.58	16.1	40.9	81	31.5	7.44	1.21
Turkey	254	1.2	4.62	12.3	54.3	35	13.8	8.03	1.97
Malaysia	242	1.2	1.49	25.8	61.6	49	20.2	1.20	0.77
Poland	227	1.1	2.09	28.1	61.7	29	12.8	7.45	5.72
Portugal	213	1.0	5.38	23.5	50.2	123	57.7	8.32	3.78
Sweden	204	1.0	5.63	16.1	45.1	72	35.3	7.79	1.61
Mexico	184	0.9	3.89	14.8	53.8	102	55.4	5.49	1.93
Israel	170	0.8	7.14	20.5	52.9	58	34.1	6.22	0.73
Russian Federation	169	0.8	0.89	49.7	69.2	29	17.2	1.55	2.05
Iran	158	0.8	3.20	16.8	60.8	19	12.0	2.47	0.70
Czech Republic	116	0.6	1.23	27.2	63.8	25	21.6	2.60	1.82
Ukraine	99	0.5	0.33	44.7	79.8	6	6.1	0.33	0.86
Norway	99	0.5	2.36	30.8	57.6	46	46.5	3.09	1.78
Greece	98	0.5	6.86	16.5	50.0	48	49.0	9.88	2.41
Austria	95	0.5	3.48	16.7	38.9	36	37.9	5.00	1.83
Belgium	93	0.5	6.83	19.3	54.8	47	50.5	10.79	3.49
Hungary	87	0.4	2.91	31.4	59.8	14	16.1	13.21	11.22
Pakistan	73	0.4	0.94	12.2	61.6	17	23.3	0.53	0.41
Romania	73	0.4	0.79	25.9	71.2	15	20.5	1.53	2.54
United Arab Emirates	73	0.4	1.85	20.0	54.8	46	63.0	2.39	2.58
Algeria	67	0.3	6.67	4.3	49.3	32	47.8	13.00	6.41
Finland	63	0.3	5.57	34.0	46.0	22	34.9	2.05	0.26
Hong Kong	61	0.3	10.25	13.8	36.1	50	82.0	11.52	1.81
South Africa	57	0.3	2.87	12.0	66.7	12	21.1	8.75	5.63

Notes: All types of documents and sources indexed in Scopus are included in the analysis. The analysis was done in 2nd decade of January 2016.

Table A.3. Key centers of excellence on UAV studies in Scopus for 1985 – 2015.

Affiliation name (as it named in Scopus)	Total number of documents (publication) 1985 – 2015	Total number of citations 1985 – 2015	Average number of citations per one document ("cites per doc")	Share in national number publications, %	Organisation "cites per doc"/National "cites per doc" ratio	Share of self citations, %
Beihang University, China, Beijing	592	1343	2.27	14.1	0.93	22.8
Northwestern Polytechnical University, China, Xi'an	457	587	1.28	10.9	0.53	18.2
Wright-Patterson AFB, USA, Dayton	442	2155	4.88	6.0	0.80	17.2
Nanjing University of Aeronautics and Astronautics, China, Nanjing	428	1033	2.41	10.2	0.99	20.2
Georgia Institute of Technology, USA, Atlanta	243	1105	4.55	3.3	0.75	23.8
University of Florida, USA, Gainesville	234	2428	10.38	3.2	1.70	20.1
Massachusetts Institute of Technology, USA, Cambridge	217	1973	9.09	2.9	1.49	16.0
University of Maryland, USA, College Park	213	1568	7.36	2.9	1.21	24.3
Cranfield University**, UK, Cranfield	213	1184	5.56	22.8	0.84	19.2
Tsinghua University, China, Beijing	189	859	4.54	4.5	1.87	14.6
Beijing Institute of Technology, China, Beijing	186	228	1.23	4.4	0.50	16.7
National University of Defense Technology, China, Changsha	181	293	1.62	4.3	0.67	11.3
Brigham Young University, USA, Provo	177	2794	15.79	2.4	2.59	10.8
Virginia Polytechnic Institute and State University, USA, Blacksburg	168	1179	7.02	2.3	1.15	26.1
Eidgenossische Technische Hochschule Zurich**, Switzerland, Zurich	163	1730	10.61	62.0	0.92	16.1
Korea Advanced Institute of Science & Technology, South Korea, Daejon	161	732	4.55	20.3	1.20	18.2
Seoul National University, South Korea, Seoul	144	696	4.83	18.1	1.28	13.5
UC Berkeley, USA, Berkeley	143	3315	23.18	1.9	3.80	9.4
National University of Singapore**, Singapore, Singapore City	139	998	7.18	54.1	1.09	16.2
University of Colorado at Boulder, usa, Boulder	136	726	5.34	1.8	0.88	20.5
University Michigan Ann Arbor, usa, Ann Arbor	134	1424	10.63	1.8	1.74	19.8
The University of Sydney, Australia, Sydney	132	838	6.35	17.1	0.99	12.6
Delft University of Technology**, Netherlands, Delft	130	355	2.73	50.2	0.93	24.5
NASA Ames Research Center, USA, Moffett Field	127	548	4.31	1.7	0.71	21.0
Naval Postgraduate School, USA, Monterey	121	921	7.61	1.6	1.25	17.9
Chinese Academy of Sciences, China, Beijing	112	367	3.28	2.7	1.35	27.0
Boeing Corporation, USA, Chicago	112	525	4.69	1.5	0.77	18.1
Naval Research Laboratory, USA, Washington	110	1036	9.42	1.5	1.54	18.2
Air Force Engineering University China, China, Xi'an	110	157	1.43	2.6	0.59	21.7
Deutsches Zentrum fur Luft- Und Raumfahrt, Germany, Cologne	107	335	3.13	12.3	0.77	23.0
Universite Concordia, Canada, Montreal	106	352	3.32	16.8	0.62	25.3
Carnegie Mellon University, USA, Pittsburgh	105	896	8.53	1.4	1.40	10.9
Royal Melbourne Institute of Technology University, Australia, Melbourne	103	380	3.69	13.4	0.57	20.8
Korea Aerospace Research Institute, South Korea, Daejon	101	240	2.38	12.7	0.63	17.9

Notes: All types of documents and sources indexed in Scopus are included in the analysis. The analysis was done in 2nd decade of January 2016. In bold key centers of excellence of a country are highlighted.