Journal of Intelligent & Fuzzy Systems 40 (2021) 1957–1970
DOI:10.3233/JIFS-189199
IOS Press

Leading countries in computer science: A bibliometric overview

Gustavo Zurita[a], José M. Merigó[a,b,*], Valeria Lobos-Ossandón[a] and Carles Mulet-Forteza[c]
[a]*Department of Management Control and Information Systems, School of Economics and Business, University of Chile, Santiago, Chile*
[b]*School of Information, Systems & Modelling, Faculty of Engineering and Information Technology, University of Technology Sydney, NSW, Australia*
[c]*Department of Business Economics, University of the Balearic Islands, Campus UIB, Palma de Mallorca, Spain*

Abstract. This paper presents a current overview of the main productive and influential countries around the world in the computer science field. Research in the computer science field has experienced significant growth in recent years. This study develops a bibliometric overview of all journals that have been indexed in the Web of Science (WoS) database over the past 25 years (1995–2019), according to several bibliometric indicators in the seven categories of computer science research. The study shows that United States is the leading country in the computer science field. Other countries, such as the United Kingdom, China, Canada and Germany, also obtain high positions in the ranking. The average country that performs research in computer science is European, has English-speaking researchers, is highly developed and has a high income. However, there is a wide range of countries that perform research in computer science, including South American and Arabic countries, meaning that computer science traverses many countries and cultures.

Keywords: Bibliometrics, countries, computer science, research productivity, ranking, Web of Science

1. Introduction

Scientific research published in indexed journals has increased exponentially in recent years because journals are the main vehicle to present new research results and thus expand the current knowledge frontier. For instance, based on data included from the Web of Science (WoS), 142.1 million documents had been published by the year 2000, whereas between the years of 2001 and 2016 alone, 86.6 million were published. Several factors are correlated with this increase, including the growing number of scholars [21]. This has led to a proliferation of bibliometric studies [19, 20], with some of them being focused on journal bibliometric analysis [14] and others analysing scholars, institutions, and countries [4].

Pritchard [29] defined the term bibliometrics as 'the application of mathematical and statistical methods to books and other means of communication'. Recently, many researchers have offered other definitions of this term [26], although most of them have in common that bibliometrics is a statistical approach to analysing published material that is based on the use of different measures or indicators, fundamentally citation analysis. The main indicators are the Impact Factor [10], the SCImago Journal Rank [13], the Eigenfactor Score [3], and the Source Normalized Impact per Paper [27].

Computer science is an empirical discipline that combines science and engineering. The hybrid nature of this field is part of its attraction but also complicates its evaluation [7]. For this reason, the main purpose of this paper is to provide a country ranking according to citations structures in WoS during a period of 25 years (1995–2019) in all computer science subfields:

*Corresponding author. José M. Merigó. E-mail: jmerigo@fen.uchile.cl.

ISSN 1064-1246/21/$35.00

Artificial Intelligence, Cybernetics, Hardware and Architecture, Information Systems, Interdisciplinary Applications, Software Engineering and Theory and Methods. Additionally, this work presents a global ranking of countries in terms of computer science.

Bibliometric papers have expanded into many different disciplines [38, 39]. In science, we can mention, among many others, papers about biology [2], meteorology [16] and energy [32]. There are many bibliometric studies in computer science [30]. Some papers have focused on the study of the main institutions [31] and journals [8, 9, 33], including Computers & Industrial Engineering [6], the International Journal of Intelligent Systems [23], Information Sciences [25] and the International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems [37]. There are also papers that have analysed countries, such as those of Godoy et al. [12] and Uddin et al. [35], although the analysis performed in these last papers focused on studying publications from specific countries, Argentina in the first work and Mexico in the second. Thus, the aim of this paper is to determine which countries are the most productive and influential in computer science and its subfields through a global analysis of the most influential journals in the field (according to the WoS). The results demonstrate that computer science research crosses many cultures and countries. There is not a significant difference among categories, but the articles came from a wide range of countries.

This work is practical for readers for several reasons. First, it is useful for scholars in terms of uncovering which countries offer more potential to develop and share research. The information will also be useful to help scholars decide on the countries where it would be interesting to perform their doctoral studies, in addition to their future research and career development. Furthermore, it will be interesting for researchers to discover the countries where research collaborations can be strengthened.

The rest of the paper is organized as follows. First, the methods section presents the bibliometric methodology used. Next, we analyse the main results dividing them in eight subsections. Finally, the conclusion summarizes the main findings, limitations and future research.

2. Methodology

WoS was the source for the selection of the panel of journals in this study. This database is considered one of the most influential in the world, together with Scopus and Google Scholar. Moreover, WoS is one of the most extensively employed databases in bibliometric studies [8].

This paper searches for articles published in journals indexed in the Web of Science categories of *Computer Science* in a 25-year period (1995–2019). The data collection was performed during April 2020. The search process is as follows:

Step 1: In WoS Core Collection search 1995–2019 in *years published*.

Step 2: The following types of documents are considered: articles, reviews, notes and letters.

Step 3: Select each of the seven Web of Science categories in order to carry out the analysis.

Step 4: For each computer science subfield, the 50 countries with the largest number of articles are selected. Note that this list is available in the online supplementary material while in the paper we only present the Top 30 countries in each list.

This paper uses several methods to represent the bibliographic data [22, 36]. First, the number of publications and citations are considered. According to Gaviria et al. [11], this is considered the most-popular bibliometric method. Whereas the number of publications quantifies productivity, the number of citations usually measures influence. The paper also makes use of the h-index [1, 15] and the ratio of 'citations per paper'. The first measures the n number of documents that have at least n citations, whereas the second measures the impact of each article [5, 34]. These two last indicators combine publications and citations into a single index [17, 18]. Furthermore, the paper also includes various citation thresholds to identify the number of documents that achieve a specific threshold [24]. This step enables identifying the number of articles with a certain amount of influence. This paper also includes the ratio of total documents per million inhabitants and total citations per million inhabitants. We have utilized several indicators in this paper because agreement about the optimal method for measuring research has not been attained.

3. Results and discussion

This section presents the main bibliometric results found in WoS for all computer science journals from 1995 to 2019. First, the paper analyzes the global results and then it analyzes the individual results for each category of the computer science field.

3.1. Global results

In this section, we present, a general picture of the global results regarding computer science.

WoS categorizes the computer science field into seven categories. The first one is 'Artificial Intelligence', which focuses on research and techniques to create machines that attempt to efficiently reason, problem-solve, use knowledge representation, and perform analyses of ambiguous information. The second area, 'Cybernetics', includes resources that focus on the control and information flows within and between artificial systems and biological systems. 'Hardware and Architecture' is the third area, which analyzes the gadgets and design that support software and systems. The fourth category is 'Information Systems', which defines a set of components for collecting, retrieving, transforming and processing data for making decisions. The fifth category is 'Interdisciplinary Applications', which includes resources concerned with the application of computer technology and methodology to other disciplines, such as engineering, and biology.

The sixth area is 'Software Engineering', which includes resources that are concerned with the programs, routines, and symbolic languages that control the functioning of hardware and direct its operation.

The last area is 'Theory and Methods', which includes resources that emphasize experimental computer processing methods or programming techniques, such as parallel computing, distributed computing, logic programming and supercomputing.

Table 1 indicates that 'Artificial Intelligence' has the highest number of journals and is the most influential category over the last 25 years in terms of number of citations. Artificial Intelligence is very helpful in areas such as business and management, in which machine learning for decision-making has a large impact and significant popularity. 'Interdisciplinary Applications' also obtains remarkable results as the category with the second largest number of papers. 'Software Engineering' and 'Theory and Methods' are very similar in terms of the number papers published and number of citations received. Then it is 'Hardware and Architecture' as the sixth more cited and productive computer science category. Finally, 'Cybernetics' is the category that publishes the least number of papers and receives the least number of citations from the computer science field. Moreover, it is the category with the least number of journals.

Next, in Table 2, we present the 50 most-productive countries in computer science research (Global Results). The ranking is listed in descending order according to the number of citations.

Table 1
Summary of global results

Category	N	TC	TP
Artificial Intelligence	134	25.8%	18.8%
Cybernetics	23	2.0%	2.3%
Hardware and Architecture	53	7.5%	8.8%
Information Systems	155	19.1%	21.7%
Interdisciplinary Applications	106	22.1%	20.1%
Software Engineering	107	11.6%	15.1%
Theory and Methods	105	11.8%	13.3%

Source: Own elaboration. Abbreviations: N = Number of journals for each category; TC = Percentage of citations of this field from the total number of citations in computer science field; TP = Percentage of papers of this field from the total number of papers in computer science field.

The top 5 countries are very influential because they constitute 58% of all citations received and 52% of all publications published by the top 50. These countries have in common a high level of resources devoted to research. The United States is the most productive country, and this country has 7% more publications than the country that occupies the second place, China. Sweden has the highest ratio of total citations per document (75.2), followed by Switzerland (33.5) and the United States (29.8). The United States is also the country with the highest h-index and the highest number of publications that received more than 250, 100 and 50 citations. Singapore, Switzerland and Israel have the highest number of citations per inhabitant. If we analyze the total number of documents per inhabitant, Singapore, Slovenia and Finland are the most productive countries.

There is a large dispersion among countries. Although the most influential countries in research are European, almost all continents are represented in these results. Nonetheless, it is also remarkable that we found three countries from the Middle East, 2 from Africa and Oceania, and 2 from South America. Instead, the results show the countries are mainly distributed in Europe and Asia.

Next, we discuss the individual results for each category of the computer science field.

3.2. Artificial Intelligence

This subfield has experienced a rapid growth over recent decades [28], in terms of both the number of papers and the number of citations. Table 3 presents the most influential countries in this area.

Table 2
Global results

R	Country	TP	TC	TC/TP	H	≥250	≥100	≥50	Population	TP/Pop	TC/Pop
1	USA	197,198	5,879,037	29.813	675	2,803	10,035	23,662	331,002,651	59.576	177.613
2	PR China	183,024	2,608,276	14.251	328	588	3,437	10,823	1,470,637,532	12.445	17.736
3	UK	56,552	1,305,790	23.090	330	510	2,123	5,433	67,886,011	83.304	192.350
4	Germany	42,343	890,765	21.037	279	333	1,382	3,656	83,783,942	50.538	106.317
5	Canada	37,722	887,504	23.527	276	319	1,358	3,516	37,742,154	99.947	235.149
6	France	40,153	799,753	19.918	266	292	1,216	3,197	65,273,511	61.515	122.523
7	Italy	33,205	608,457	18.324	220	179	837	2,385	60,461,826	54.919	100.635
8	Spain	35,061	589,958	16.827	215	167	773	2,249	46,754,778	74.989	126.181
9	Australia	25,739	564,819	21.944	220	169	894	2,436	25,499,884	100.938	221.499
10	Netherlands	16,364	450,034	27.501	233	207	746	1,853	17,134,872	95.501	262.642
11	Japan	32,265	400,082	12.400	180	101	509	1,508	126,476,461	25.511	31.633
12	South Korea	30,821	397,116	12.885	180	100	501	1,502	51,269,185	60.116	77.457
13	India	28,859	380,859	13.197	165	75	405	1,325	1,380,004,385	2.091	2.760
14	Switzerland	11,279	377,332	33.454	212	172	630	1,440	8,654,622	130.323	435.989
15	Singapore	13,968	331,414	23.727	186	113	529	1,471	5,850,342	238.755	566.487
16	Israel	11,436	296,953	25.967	201	151	491	1,180	8,655,535	132.124	343.079
17	Belgium	10,230	251,274	24.562	174	99	385	1,022	11,589,623	88.269	216.809
18	Turkey	12,731	216,027	16.969	149	49	295	954	84,339,067	15.095	25.614
19	Iran	16,322	200,928	12.310	121	26	193	737	83,992,949	19.433	23.922
20	Sweden	2,548	192,687	75.623	149	67	243	751	10,099,265	25.230	190.793
21	Greece	10,200	176,814	17.335	136	37	236	768	10,423,054	97.860	169.637
22	Finland	7,413	176,467	23.805	150	75	272	665	5,540,720	133.791	318.491
23	Brazil	14,514	172,164	11.862	130	37	205	570	212,559,417	6.828	8.100
24	Austria	8,161	167,878	20.571	146	60	263	712	9,006,398	90.613	186.399
25	Denmark	5,943	138,569	23.316	133	60	212	574	5,792,202	102.603	239.234
26	Poland	9,801	136,698	13.947	116	37	158	473	37,846,611	25.897	36.119
27	Portugal	6,797	120,071	17.665	120	35	163	451	10,196,709	66.659	117.755
28	Norway	5,484	106,377	19.398	129	35	175	465	5,421,241	101.158	196.223
29	Saudi Arabia	6,929	90,253	13.025	102	9	112	370	34,813,871	19.903	25.924
30	Malaysia	5,665	82,437	14.552	98	17	92	316	32,365,999	17.503	25.470

Source: Own elaboration. Abbreviations: (1) Total Papers (TP), which indicates the numbers of papers associated for each country; (2) Total Citations (TC), that means the sum of citations obtained by the selected country; (3) Total Citations/Total Papers (TC/TP) it is a ratio for the average number of citations for each published article; (4) h-index, which indicates X number of articles that have at least X number of citations (Hirsch, 2005); (5) ≥250, that indicates the papers that have at least 250 citations; (6) ≥100, which specifies the number of papers that have at least 100 citations; (7) ≥50, that identifies the number of papers that have at least 50 citations; (8), population in 2020; (9), TP/Pop, Number of papers per one million inhabitants; (10), TC/Pop, Number of citations per one million inhabitants.

The results for this category are representative of the global results. These results are not surprising, especially if we take into account that Artificial Intelligence is the most important subarea of the computer science field (Table 1). Almost all computing countries, except for Jordan, are the same for both Artificial Intelligence and the global results. In addition, we can see how the countries are practically the same. The only difference is that in Artificial Intelligence, South Africa is not represented and has been replaced by Jordan.

The average number of publications in Table 3 is 4,935, finding only 14 of the 50 countries that match or exceed this average. The 5 most prolific countries in number of publications are China (21.48%), the United States (15.52%), the United Kingdom (6.17%), Spain (4.49%), and France (4.03%). The h-index exhibits a pattern similar to the ranking of publications for the three most productive countries. The first three countries in terms of production are exactly the same as in terms of the h-index, although there are some differences in terms of the specific positions that these countries occupy. If we analyze these same publications, but taking into account the population of each of the countries, the results obtained are quite different. In this case, 21 countries reach the average number of publications per population, with the five most productive countries being Singapore (10.82%), Slovenia (5.47%), Finland (4.72%), Switzerland (4.28%) and Australia (4.17%). If we compare the rankings of total documents and total papers per inhabitant, it is observed that only three countries occupy prominent positions in both of these two rankings (Singapore, Slovenia and Finland).

In reference to the total number of citations, it is worth mentioning that the results are very similar to those obtained when analyzing the publications.

Table 3
Artificial intelligence

R	Country	TP	TC	TC/TP	H	≥250	≥100	≥50	Population	TP/Pop	TC/Pop
1	USA	38,292	1,665,105	43.484	453	932	2,821	6,028	331,002,651	115.685	5,030.488
2	PR China	53,011	1,116,059	21.053	270	318	1,779	5,094	1,470,637,532	36.046	758.895
3	UK	15,233	495,652	32.538	245	241	865	1,972	67,886,011	224.391	7,301.239
4	France	9,954	278,472	27.976	186	126	452	1,140	65,273,511	152.497	4,266.233
5	Canada	8,047	272,223	33.829	183	109	422	1,021	37,742,154	213.210	7,212.704
6	Germany	8,242	252,015	30.577	188	116	433	1,025	83,783,942	98.372	3,007.915
7	Spain	11,088	234,012	21.105	157	78	350	945	46,754,778	237.152	5,005.093
8	Australia	6,987	189,425	27.111	160	63	346	883	25,499,884	274.001	7,428.465
9	India	9,019	163,280	18.104	128	42	200	596	1,380,004,385	6.535	118.318
10	Italy	7,896	161,494	20.453	138	47	258	704	60,461,826	130.595	2,671.008
11	Singapore	4,154	147,795	35.579	147	63	258	655	5,850,342	710.044	25,262.626
12	Japan	6,095	140,257	23.012	135	51	210	565	126,476,461	48.191	1,108.957
13	Switzerland	2,431	136,194	56.024	143	77	236	463	8,654,622	280.890	15,736.562
14	Netherlands	3,592	131,835	36.702	143	70	223	507	17,134,872	209.631	7,693.959
15	South Korea	6,107	123,064	20.151	120	33	167	529	51,269,185	119.116	2,400.350
16	Turkey	5,314	96,711	18.199	115	23	146	466	84,339,067	63.008	1,146.693
17	Israel	2,350	96,284	40.972	127	58	162	360	8,655,535	271.503	11,123.980
18	Belgium	2,580	88,857	34.441	112	39	136	344	11,589,623	222.613	7,666.945
19	Iran	6,031	80,823	13.401	93	11	77	318	83,992,949	71.804	962.259
20	Finland	1,718	74,327	43.264	105	35	113	236	5,540,720	310.068	13,414.683
21	Greece	2,515	55,608	22.111	94	17	85	262	10,423,054	241.292	5,335.097
22	Brazil	3,207	51,441	16.040	86	13	66	187	212,559,417	15.088	242.008
23	Sweden	1,804	46,403	25.722	87	14	65	182	10,099,265	178.627	4,594.691
24	Poland	2,835	45,292	15.976	74	9	46	166	37,846,611	74.908	1,196.725
25	Portugal	1,879	43,835	23.329	83	20	59	161	10,196,709	184.275	4,298.936
26	Austria	1,576	39,490	25.057	80	13	63	178	9,006,398	174.987	4,384.661
27	Denmark	1,205	35,365	29.349	84	19	63	139	5,792,202	208.038	6,105.623
28	Malaysia	2,104	34,531	16.412	71	6	37	130	32,365,999	65.006	1,066.891
29	Saudi Arabia	1,904	33,017	17.341	80	3	49	162	34,813,871	54.691	948.386
30	Mexico	1,914	30,094	15.723	73	9	37	120	128,932,753	14.845	233.408

Source: Own elaboration. Abbreviations are available in Table 2.

In this case there are 13 countries that equal or exceed the average (United States, China, United Kingdom, France, Canada, Germany, Spain, Australia, India, Italy, Singapore, Japan and Switzerland). Approximately 50% of citations are concentrated in three countries (United States, China and United Kingdom). If in the previous analysis we take into account the population, in this case 21 countries would be those that exceed the average, leading this ranking Singapore (10.82%), Slovenia (5.47%), Finland (4.72%), Switzerland (4.28%) and Australia (4.17%).

Regarding the total number of citations, it is worth mentioning that the results are very similar to those obtained when analyzing the publications. In this case, there are 13 countries that equal or exceed the average (the United States, China, the United Kingdom, France, Canada, Germany, Spain, Australia, India, Italy, Singapore, Japan, and Switzerland). Approximately 50% of citations are concentrated in three countries (the United States, China and the United Kingdom). If in the previous analysis we take into account the population, in this case, 20 countries would be those that exceed the average, with Singapore (13.22%), Switzerland (8.24%), Finland (7.02%), Slovenia (6.29%), and Israel (5.82%) leading this ranking.

Regarding the ratio of citations per documents, the countries that lead this classification are Switzerland, Finland, the United States, Israel, Netherlands and Singapore. Regarding the documents that obtain thresholds of 250, 100 and 50 citations, we can see how only three countries account for more than 50% of the total number of documents that exceed those thresholds. Specifically, the United States accounts for 34.29% of all documents that obtain a threshold of at least 250 citations, 26.81% of those that obtain a threshold of at least 100 citations, and 22.76% of all documents that obtain a threshold of at least 50 citations.

3.3. Cybernetics

Cybernetics is the area with the fewest number of journals. The number of research papers published has experienced a slight increment in the consid-

Table 4
Cybernetics

R	Country	TP	TC	TC/TP	H	≥250	≥100	≥50	Population	TP/Pop	TC/Pop
1	USA	4,956	123,891	24.998	129	38	213	577	331,002,651	14.97	374.29
2	PR China	4,241	84,581	19.944	108	11	142	441	1,470,637,532	2.88	57.51
3	UK	2,684	54,695	20.378	98	15	96	266	67,886,011	39.54	805.69
4	Germany	1,237	23,764	19.211	69	3	28	113	83,783,942	14.76	283.63
5	Australia	914	21,964	24.031	72	4	43	121	25,499,884	35.84	861.34
6	Canada	923	19,038	20.626	66	6	33	90	37,742,154	24.46	504.42
7	France	955	16,843	17.637	59	3	31	73	65,273,511	14.63	258.04
8	Italy	867	15,879	18.315	58	4	28	72	60,461,826	14.34	262.63
9	Netherlands	659	13,950	21.168	55	3	24	62	17,134,872	38.46	814.13
10	Japan	751	12,577	16.747	52	7	21	60	126,476,461	5.94	99.44
11	Spain	955	10,863	11.375	45	1	9	36	46,754,778	20.43	232.34
12	South Korea	617	10,524	17.057	47	3	15	39	51,269,185	12.03	205.27
13	Singapore	351	8,633	24.595	48	1	12	47	5,850,342	60.00	1,475.64
14	Switzerland	305	8,365	27.426	45	3	23	42	8,654,622	35.24	966.54
15	Sweden	340	6,504	19.129	38	2	14	26	10,099,265	33.67	644.01
16	Israel	275	5,897	21.444	36	3	6	25	8,655,535	31.77	681.30
17	Russia	2,267	4,682	2.065	18	0	2	5	145,934,462	15.53	32.08
18	Finland	308	4,497	14.601	33	2	4	19	5,540,720	55.59	811.63
19	Denmark	254	4,368	17.197	34	1	6	20	5,792,202	43.85	754.12
20	Austria	260	3,843	14.781	32	1	5	15	9,006,398	28.87	426.70
21	Norway	428	3,782	8.836	29	0	3	14	5,421,241	78.95	697.63
22	Poland	312	3,780	12.115	26	2	4	8	37,846,611	8.24	99.88
23	Saudi Arabia	172	3,404	19.791	32	0	6	19	34,813,871	4.94	97.78
24	New Zealand	146	3,374	23.110	31	1	5	15	4,822,233	30.28	699.68
25	Saudi Arabia	172	3,363	19.552	32	0	6	18	34,813,871	4.94	96.60
26	Greece	249	3,350	13.454	31	0	3	13	10,423,054	23.89	321.40
27	India	342	3,082	9.012	28	0	1	10	1,380,004,385	0.25	2.23
28	Czech Republic	513	2,873	5.600	22	1	2	5	10,708,981	47.90	268.28
29	Turkey	261	2,678	10.261	27	0	1	11	84,339,067	3.09	31.75
30	Belgium	170	2,566	15.094	25	1	5	10	11,589,623	14.67	221.40

Source: Own elaboration. Abbreviations are available in Table 2.

ered time span of 15 years (1997–2011), exhibiting some ups and downs throughout said time period [30]. Table 4 lists the most influential countries in this category.

The average number of publications in this field is 581 (13 countries have a number equal to or exceeding this average). The 5 most prolific countries are the United States (17.05%), China (14.59%), the United Kingdom (9.23%), Russia (7.80%), and Germany (5.25%). The first three countries are exactly the same as in terms of the h-index. If we take into account the population of each of the countries, the results obtained are quite different. In this case, 20 countries are those that reach the average of publications by population, with the most important countries being Norway (8.04%), Slovenia (7.60%), Singapore (6.11%), Finland (5.66%), and Czech Republic (4.90%).

Regarding the total number of citations, it is worth mentioning that the results are very similar to those for publications. In this case, there are 12 countries that exceed the average. The five most-cited countries are the United States (24.49%), China (16.72%), the United Kingdom (10.81%), Germany (4.70%), and Australia (4.34%). Approximately 52% of citations are concentrated in the first three countries. It should also be noted that almost a third of the citations are received by the United States. If we take into account the population, it is observed that 18 countries surpass the average, with the 5 main countries being Singapore (9.66%), Switzerland (6.33%), Australia (5.64%), Netherlands (5.33%), and Finland (5.31%).

Regarding the ratio citations per documents, the countries that lead this classification are Switzerland, the United States, Singapore, Australia, and Qatar. If we analyze the number of documents that obtain thresholds of 250, 100 and 50 citations, we can see how the United States, China and the United Kingdom together account for 55% of the total documents that obtain the thresholds cited. The United States has the majority of documents that obtain these thresholds (32%, 27% and 25%, respectively). The last eleven countries do not have articles cited more than 50 times. This result means that the development of the research in Cybernetics is concentrated in a few countries.

3.4. Hardware and architecture

This category has the biggest difference in countries with respect to the global ranking: five countries of this category are not in the global results. Additionally, the average GDP per capita is the highest for this computer science category. Moreover, according to Singh et al. [31], the number of papers published in this area has experienced uneven growth. Table 5 presents the most influential countries in this category.

The average of publications in Table 5 is 2,207, with only 12 of the 50 countries matching or exceeding this average. The 5 most prolific countries in number of publications are the United States (26.54%), China (22.16%), Japan (13.60%), Canada (8.59%), and South Korea (9.21%). The h-index shows a pattern similar to the ranking of publications. The first 10 countries in terms of production are almost the same as those in terms of the h-index, although there are some differences in terms of the specific positions that these countries occupy. If we analyze these same publications, but taking into account the population of each of the countries, the results obtained are quite different. In this case, 24 countries reach the average number of publications per population, with the five most productive countries being Singapore (9.91%), Israel (4.78%), Cyprus (4.50%), Greece (4.73%), and Finland (4.65%). Although the results for the first 20 countries in the rank are similar to the global results, in the last places of the ranking, there are Arabic countries, such as Cyprus and Lebanon, who appears in the results for the first time. In this sense, this category has a strong presence of Middle Eastern countries.

Regarding the total number of citations, it is worth mentioning that the results are very similar to those obtained when analyzing the publications. In this case, there are 10 countries that equal or exceed the average (the United States, China, Canada, the United Kingdom, Italy, Germany, Japan, France, Australia, and South Korea). Approximately 42% of citations are concentrated in the United States. If we take into account the population, in this case, 20 countries exceed the average, including Singapore (10.50%), Israel (8.35%), Switzerland (5.54%), the United States (5.16%), and Canada (4.70%).

Regarding the ratio citations per documents, the countries that lead this classification are Israel, the United States, Qatar, Romania, and Switzerland. Regarding the documents that obtain thresholds of 250, 100 and 50 citations, we can see how the United States alone accounts for more than 46% of the total number of documents that exceed those thresholds. Specifically, the United States accounts for 57% of all documents that obtain a threshold of at least 250 citations, 48% of those that obtain a threshold of at least 100 citations, and 44% of all documents that obtain a threshold of at least 50 citations.

3.5. Information Systems

Information Systems is a growing category in the computer science field, since it is related to many scientific areas, such as business and engineering. Table 6 presents the most influential countries in the Information Systems category.

The average of publications in Table 6 is 5,750, with only 12 of the 50 countries matching or exceeding this average. The 5 most prolific countries in terms of number of publications are China (24.35%), the United States (19.42%), Japan (5.47%), South Korea (4.79%), and the United Kingdom (4.66%). The h-index exhibits a pattern similar to the ranking of publications. The first 15 countries in terms of production are almost the same as those in terms of the h-index, although there are some differences in terms of the specific positions that these countries occupy. If we analyze these same publications, but taking into account the population of each of the countries, the results obtained are quite different. In this case, 22 countries reach the average number of publications per population, with the three most productive countries being Singapore (10.72%), Finland (5.51%), and Israel (4.17%).

The average of citations in Table 6 is 95,659, with only 11 of the 50 countries matching or exceeding this average. The 5 most prolific countries in terms of number of citations are United States (34.33%), China (14.92%), the United Kingdom (5.23%), Canada (4.87%), and Germany (3.61%). The h-index exhibits a pattern similar to the ranking of publications. The first 15 countries in terms of production are almost the same as those in terms of the h-index, although there are some differences in terms of the specific positions that these countries occupy. If we analyze these same publications, but taking into account the population of each of the countries, the results obtained are quite different. In this case, 19 countries reach the average number of citations per population, with the three most cited countries being Singapore (11.71%), Switzerland (6.12%), and Finland (5.94%).

Table 5
Hardware architecture

R	Country	TP	TC	TC/TP	H	≥250	≥100	≥50	Population	TP/Pop	TC/Pop
1	USA	29,865	766,986	25.682	285	350	1,351	3,231	331,002,651	90.226	2,317.160
2	PR China	18,326	222,661	12.150	140	32	278	912	1,470,637,532	12.461	151.404
3	Canada	4,730	79,655	16.840	107	22	126	355	37,742,154	125.324	2,110.505
4	UK	4,376	76,055	17.380	109	26	124	307	67,886,011	64.461	1,120.334
5	Italy	3,731	67,676	18.139	94	19	81	239	60,461,826	61.708	1,119.318
6	Germany	3,401	57,979	17.048	97	21	94	258	83,783,942	40.593	692.006
7	Japan	8,739	51,361	5.877	75	7	50	139	126,476,461	69.096	406.091
8	France	3,284	47,582	14.489	85	11	61	186	65,273,511	50.311	728.963
9	Australia	2,373	42,496	17.908	90	9	78	200	25,499,884	93.059	1,666.517
10	South Korea	4,687	41,643	8.885	81	10	55	141	51,269,185	91.419	812.242
11	Spain	3,272	36,225	11.071	66	6	26	108	46,754,778	69.982	774.787
12	Israel	1,175	32,459	27.625	74	21	60	119	8,655,535	135.751	3,750.086
13	India	3,642	31,987	8.783	65	5	30	98	1,380,004,385	2.639	23.179
14	Singapore	1,648	27,573	16.731	69	7	34	114	5,850,342	281.693	4,713.058
15	Netherlands	1,190	22,544	18.945	64	7	33	98	17,134,872	69.449	1,315.680
16	Switzerland	1,077	21,513	19.975	64	9	39	88	8,654,622	124.442	2,485.724
17	Greece	1,402	19,455	13.877	62	1	29	80	10,423,054	134.510	1,866.535
18	Sweden	999	16,414	16.430	53	8	18	59	10,099,265	98.918	1,625.267
19	Iran	1,976	14,430	7.303	44	2	11	33	83,992,949	23.526	171.800
20	Belgium	998	13,496	13.523	50	4	12	50	11,589,623	86.112	1,164.490
21	Turkey	1,073	13,404	12.492	49	2	17	49	84,339,067	12.722	158.930
22	Brazil	1,147	11,573	10.090	44	2	13	40	212,559,417	5.396	54.446
23	Finland	732	10,668	14.574	46	4	14	40	5,540,720	132.113	1,925.382
24	Austria	527	10,490	19.905	45	7	22	40	9,006,398	58.514	1,164.728
25	Saudi Arabia	700	9,643	13.776	47	0	15	40	34,813,871	20.107	276.987
26	Ireland	476	8,235	17.300	40	4	11	28	4,937,786	96.399	1,667.751
27	Portugal	649	8,137	12.538	39	1	11	27	10,196,709	63.648	798.003
28	Poland	517	7,584	14.669	42	3	10	30	37,846,611	13.660	200.388
29	Malaysia	438	6,852	15.644	40	1	10	30	32,365,999	13.533	211.704
30	Denmark	435	6,355	14.609	38	1	5	31	5,792,202	75.101	1,097.165

Source: Own elaboration. Abbreviations are available in Table 2.

Regarding the ratio citations per documents, the countries that lead this classification are the United States, Switzerland, Netherlands, Israel, and Canada. Regarding the documents that obtain thresholds of 250, 100 and 50 citations, we can see how the United States alone accounts for more than 37% of the total number of documents that exceed the first two thresholds, and together, the United States and China account for slightly more than 50% of the papers that have more than 50 citations.

3.6. Interdisciplinary applications

This area is the most productive in computer science research, since it is an interdisciplinary area that embraces articles from many knowledge areas, such as biology, medicine and engineering. Table 7 presents the most influential countries in this category.

The average number of publications in Table 7 is 5,236, with only 14 of the 50 countries matching or exceeding this average. The 5 most prolific countries in number of publications are the United States (25.55%), China (7.61%), the United Kingdom (7.08%), Germany (5.08%) and France (4.88%). It can be observed how the three leading countries in this field also head the rankings of Information Systems, Hardware Architecture, Cybernetics and Artificial Intelligence. The h-index exhibits a similar pattern to the ranking of publications. The first 10 countries in terms production are the same as those in terms of the h-index. If we analyze the publications taking into account the population of each of the countries, we can observe how 24 countries reach the average number of publications per population, with the three most productive countries being Slovenia (7.11%), Singapore (7.05%) and Switzerland (5.08%). Slovenia and Singapore occupies predominant positions in this ranking, as is the case for Slovenia also for Artificial Intelligence and Cybernetics and for Singapore also for Artificial Intelligence, Hardware Architecture, and Information Systems.

In terms of the total number of citations, it is worth mentioning that the results are very similar to those obtained when analyzing the publications. In this case, there are 12 countries that equal or exceed

Table 6
Information systems

R	Country	TP	TC	TC/TP	H	≥250	≥100	≥50	Population	TP/Pop	TC/Pop
1	United States	40,252	804,265	19.98	296	373	1,333	3153	324,118,787	1.242	24.814
2	PR China	15,155	111,901	7.33	101	20	131	492	1,382,323,332	0.110	0.804
3	Canada	6,515	99,462	15.27	124	48	156	384	36,286,378	1.795	27.410
4	United Kingdom	7,581	85,876	11.33	102	22	110	311	65,111,143	1.164	13.189
5	Germany	5,376	62,895	11.70	92	13	78	211	80,682,351	0.666	7.795
6	France	4,045	56,058	13.86	90	28	78	193	64,668,129	0.626	8.669
7	Taiwan	6,362	48,466	7.62	75	6	43	175	23,395,600	2.719	20.716
8	Australia	3,623	44,615	12.31	78	12	52	177	24,309,330	1.490	18.353
9	Italy	3,816	43,966	11.52	74	14	47	131	59,801,004	0.638	7.352
10	Israel	2,040	40,525	19.87	82	17	65	179	8,192,463	2.490	49.466
11	Netherlands	2,442	40,319	16.51	86	20	67	170	16,979,729	1.438	23.745
12	South Korea	6,471	37,978	5.87	68	6	35	113	50,503,933	1.281	7.520
13	Japan	6,913	37,879	5.48	67	8	34	109	126,323,715	0.547	2.999
14	Switzerland	1,515	32,682	21.57	75	18	53	120	8,379,477	1.808	39.002
15	Spain	3,515	29,909	8.51	63	5	24	100	46,064,604	0.763	6.493
16	Singapore	2,135	24,563	11.50	63	6	33	95	5,696,506	3.748	43.119
17	India	2,348	16,778	7.15	49	2	15	49	1,326,801,576	0.018	0.126
18	Finland	1,214	15,524	12.79	53	5	25	57	5,523,904	2.198	28.103
19	Greece	1,759	14,974	8.51	48	1	9	45	10,919,459	1.611	13.713
20	Sweden	1,163	13,207	11.36	45	4	15	38	9,851,852	1.180	13.406
21	Belgium	1,174	12,972	11.05	53	0	16	62	11,371,928	1.032	11.407
22	Poland	939	12,073	12.86	47	7	14	44	38,593,161	0.243	3.128
23	Austria	893	11,511	12.89	47	3	16	46	8,569,633	1.042	13.432
24	Turkey	880	10,300	11.70	45	2	11	41	79,622,062	0.111	1.294
25	Denmark	765	9,934	12.99	43	3	9	37	5,690,750	1.344	17.456
26	Norway	792	8,790	11.10	42	0	4	35	5,271,958	1.502	16.673
27	Brazil	1,650	8,548	5.18	41	0	8	24	209,567,920	0.079	0.408
28	New Zealand	656	8,219	12.53	40	3	14	30	4,565,185	1.437	18.004
29	Iran	981	7,223	7.36	34	1	2	19	80,043,146	0.123	0.902
30	Ireland	675	6,241	9.25	36	0	6	25	4,713,993	1.432	13.239

Source: Own elaboration. Abbreviations are available in Table 2.

the average. The five most-cited countries are the United States (28.11%), China (10.00%), the United Kingdom (6.96%), Germany (5.29%), and France (4.44%). Approximately 50% of citations are concentrated in the first four countries. If we take into account the population, in this case, 22 countries exceed the average, with this ranking led by Switzerland (8.21%), Singapore (6.86%), Denmark (6.13%), Netherlands (6.12%), and Slovenia (5.61%).

Regarding the ratio of citations per document, the countries that lead this classification are Switzerland, the Netherlands, Denmark, the United States, and Belgium. Regarding the documents that obtain thresholds of 250, 100 and 50 citations, we can see how the United States account for more than 30% of the total number of documents that exceed those thresholds. Specifically, the United States accounts for 36% of all documents that obtain a threshold of at least 250 citations, 32% of those that obtain a threshold of at least 100 citations, and 29% of all documents that obtain a threshold of at least 50 citations.

3.7. Software engineering

This area includes scientific articles for the study of the development, maintenance and principles of software, and the main objectives of this research area are software principles and techniques. Table 8 presents the most influential countries in this area.

The average number of publications in this field is 3,435 (12 countries have a number equal to or exceeding this average). The 5 most prolific countries are the United States (22.26%), China (15.88%), the United Kingdom (5.65%), Germany (5.29%), and Japan (4.46%). The first 10 countries in terms of production are the same as in terms of the h-index, except for Japan. If we take into account the population of each of the countries, the results obtained are quite different. In this case, 23 countries reach the average of publications by population, with the 5 most important countries being Singapore (7.90%), Luxembourg (6,76%), Switzerland (5.57%), Israel (5.08%), and Austria (4.89%).

Table 7
Interdisciplinary applications

R	Country	TP	TC	TC/TP	H	≥250	≥100	≥50	Population	TP/Pop	TC/Pop
1	USA	56,440	1,528,584	27.083	345	587	2,505	6,495	331,002,651	170.512	4,618.042
2	PR China	37,367	543,981	14.558	175	81	600	2,118	1,470,637,532	25.409	369.895
3	UK	15,972	378,614	23.705	197	126	589	1,671	67,886,011	235.277	5,577.202
4	Germany	12,656	287,375	22.707	184	106	449	1,260	83,783,942	151.055	3,429.953
5	France	11,531	241,546	20.948	164	75	374	1,003	65,273,511	176.657	3,700.521
6	Canada	9,548	223,405	23.398	148	60	312	862	37,742,154	252.980	5,919.244
7	Italy	9,268	180,597	19.486	136	48	243	711	60,461,826	153.287	2,986.959
8	Spain	9,835	175,840	17.879	134	39	227	719	46,754,778	210.353	3,760.899
9	Netherlands	5,253	169,395	32.247	154	68	294	724	17,134,872	306.568	9,885.980
10	Australia	6,868	151,492	22.058	137	46	231	617	25,499,884	269.335	5,940.890
11	India	8,992	117,970	13.119	104	16	112	422	1,380,004,385	6.516	85.485
12	Switzerland	3,224	114,743	35.590	127	43	175	425	8,654,622	372.518	13,258.002
13	Japan	6,033	94,530	15.669	102	25	109	375	126,476,461	47.701	747.412
14	Iran	6,131	89,831	14.652	96	14	88	348	83,992,949	72.994	1,069.506
15	Belgium	3,473	87,903	25.310	112	29	131	372	11,589,623	299.665	7,584.630
16	South Korea	5,908	87,851	14.870	103	13	108	337	51,269,185	115.235	1,713.524
17	Turkey	4,328	78,910	18.232	99	16	98	333	84,339,067	51.317	935.628
18	Sweden	2,697	66,833	24.780	93	25	84	247	10,099,265	267.049	6,617.610
19	Singapore	3,023	64,834	21.447	100	17	101	306	5,850,342	516.722	11,082.087
20	Brazil	4,531	58,706	12.957	85	14	66	187	212,559,417	21.316	276.186
21	Denmark	1,869	57,394	30.708	98	27	97	235	5,792,202	322.675	9,908.840
22	Austria	2,170	51,354	23.665	96	25	93	214	9,006,398	240.940	5,701.947
23	Greece	2,866	50,073	17.471	84	6	56	205	10,423,054	274.967	4,804.062
24	Portugal	2,293	44,587	19.445	82	8	61	187	10,196,709	224.876	4,372.685
25	Poland	3,044	41,826	13.740	79	11	53	140	37,846,611	80.430	1,105.145
26	Finland	1,743	37,405	21.460	80	14	60	171	5,540,720	314.580	6,750.928
27	Russia	1,825	37,229	20.399	70	19	44	108	145,934,462	12.506	255.108
28	Israel	1,776	36,116	20.336	76	9	48	146	8,655,535	205.187	4,172.590
29	Norway	1,493	31,962	21.408	78	9	56	152	5,421,241	275.398	5,895.698
30	Malaysia	1,627	30,805	18.934	72	5	38	132	32,365,999	50.269	951.770

Source: Own elaboration. Abbreviations are available in Table 2.

Regarding the total number of citations, it is worth mentioning that the results are very similar to those in terms of publications. In this case, there are 11 countries that exceed the average. The three most-cited countries are the United States (34.11%), China (10.08%), and the United Kingdom (6.22%). If we take into account the population, it is observed that 21 countries exceeded the average, with the 3 main countries being Israel (9.32%), Singapore (7.96%), and Switzerland (7.07%).

Regarding the ratio citations per documents, the countries that lead this classification are Israel, the United States and Norway. If we analyze the number of documents that obtain thresholds of 250, 100 and 50 citations, we can see how the United States receives more than 39% of the total documents that obtain the thresholds cited (47%, 42% and 37%, respectively).

3.8. Theory and methods

Theory and Methods is the area that studies the principles and techniques of computer science. Table 9 presents the most influential countries in this category.

The average number of publications in this field is 3,533 (only 13 countries have a number equal to or exceeding this average). The 5 most prolific countries are the United States (19.96%), China (14.97%), the United Kingdom (6.08%), France (5.17%), and Germany (5.15%). The first 10 countries in terms production are the same as those in terms of the h-index. If we take into account the population of each of the countries, the results obtained are quite different. In this case, 25 countries are those that reach the average of publications by population, with the 5 most important countries being Singapore (7.84%), Israel (7.41%), Finland (4.72%), Switzerland (4.46%), and Austria (4.22%).

Regarding the total number of citations, the results are very similar to those in terms of publications. In this case, there are 11 countries that exceed the average. The five most-cited countries are the United States (28.72%), China (11.89%), the United Kingdom (7.00%), Germany (4.77%), and France (4.36%). If we take into account the population, it

Table 8
Software engineering

R	Country	TP	TC	TC/TP	H	≥250	≥100	≥50	Population	TP/Pop	TC/Pop
1	USA	38,241	964,024	25.209	310	445	1,757	4,277	331,002,651	115.531	2,912.436
2	PR China	27,274	284,848	10.444	141	41	280	1,047	1,470,637,532	18.546	193.690
3	UK	9,708	175,790	18.108	153	61	284	736	67,886,011	143.004	2,589.488
4	Germany	9,083	160,790	17.702	145	55	260	685	83,783,942	108.410	1,919.103
5	Canada	6,611	125,744	19.020	123	33	177	550	37,742,154	175.162	3,331.659
6	France	7,286	117,296	16.099	119	35	158	475	65,273,511	111.623	1,796.992
7	Italy	6,063	96,004	15.834	108	24	123	397	60,461,826	100.278	1,587.845
8	Australia	4,164	72,555	17.424	103	20	106	299	25,499,884	163.295	2,845.307
9	Israel	2,278	68,822	30.212	114	42	126	268	8,655,535	263.184	7,951.213
10	Spain	5,557	63,154	11.365	79	12	52	192	46,754,778	118.854	1,350.750
11	Netherlands	3,128	60,646	19.388	97	23	97	257	17,134,872	182.552	3,539.332
12	Japan	7,654	56,327	7.359	85	8	63	189	126,476,461	60.517	445.356
13	Switzerland	2,495	52,211	20.926	95	12	91	257	8,654,622	288.285	6,032.730
14	South Korea	5,797	52,023	8.974	80	9	46	182	51,269,185	113.070	1,014.703
15	Austria	2,280	41,609	18.250	84	8	59	179	9,006,398	253.153	4,619.938
16	Singapore	2,394	39,720	16.591	77	13	42	166	5,850,342	409.207	6,789.347
17	India	3,635	36,029	9.912	72	7	39	123	1,380,004,385	2.634	26.108
18	Belgium	1,585	31,039	19.583	73	16	46	135	11,589,623	136.760	2,678.172
19	Sweden	1,917	31,001	16.172	70	9	36	125	10,099,265	189.816	3,069.629
20	Brazil	2,700	27,835	10.309	61	3	32	80	212,559,417	12.702	130.952
21	Greece	1,806	24,032	13.307	59	7	24	84	10,423,054	173.270	2,305.658
22	Norway	1,041	23,589	22.660	65	12	49	96	5,421,241	192.022	4,351.218
23	Turkey	1,318	17,571	13.332	58	3	16	73	84,339,067	15.627	208.338
24	Finland	1,191	17,256	14.489	53	5	24	61	5,540,720	214.954	3,114.397
25	Iran	1,457	16,080	11.036	50	3	11	54	83,992,949	17.347	191.445
26	Czech Republic	954	15,494	16.241	43	5	18	40	10,708,981	89.084	1,446.823
27	Ireland	859	15,473	18.013	57	5	16	67	4,937,786	173.965	3,133.591
28	Denmark	911	15,446	16.955	53	5	20	62	5,792,202	157.280	2,666.689
29	Poland	1,548	13,505	8.724	46	1	5	38	37,846,611	40.902	356.835
30	New Zealand	750	11,417	15.223	49	3	17	49	4,822,233	155.530	2,367.575

Source: Own elaboration. Abbreviations are available in Table 2.

is observed that 24 countries exceeded the average, with the 3 top countries being Singapore (9.59%), Israel (8.45%), and Switzerland (7.00%).

Regarding the ratio of citations per documents, the countries that lead this classification are Switzerland, the United States, Australia, Singapore, and the United Kingdom. If we analyze the number of documents that obtain thresholds of 250, 100 and 50 citations, we can see how the United States, the United Kingdom and China account for more than 56% of the total number of documents that exceed those thresholds. Specifically, the United States accounts for 37% of all documents that obtain a threshold of at least 250 citations, 32% of those that obtain a threshold of at least 100 citations, and 30% of all documents that obtain a threshold of at least 50 citations, whereas the percentages are 8.38%, 8.15% and 7.00%, respectively, for the United Kingdom and 7.23%, 11.23%, and 13.03%, respectively, for China.

4. Conclusions

This study aims to characterize computer science research countries that are indexed in the WoS database between 1995 and 2019. This analysis illustrates the results obtained for an extensive range of bibliometric indicators, such as citation analysis, the impact factor and the h-index. The general results are more useful from a broader perspective than the Journal Citation Reports of the WoS for providing PhD students and newcomers in the field with a general orientation of the leading countries in computer science.

The results provide a general picture of the current position of the leading countries in this field for the seven analysed categories. A total of 60 countries have a presence in the elaborated ranks, which obtained 18,578,557 citations. Almost 60% of these are obtained by only 5 countries (the United States, the United Kingdom, China, Canada and Germany), which indicates the relevance and influence of these countries in the computer science field. Only 28 countries obtain more than 100,000 citations, and only 15 countries obtain more than 100 documents with 250 or more citations.

The United States is the country that publishes the most in all of the disciplines analysed, except in Artificial Intelligence and Information Systems, where

Table 9
Theory and methods

R	Country	TP	TC	TC/TP	H	≥250	≥100	≥50	Population	TP/Pop	TC/Pop
1	USA	35,970	862,312	23.973	293	386	1,439	3,494	331,002,651	10.867	26.052
2	PR China	26,971	357,004	13.237	166	75	485	1,502	1,470,637,532	1.834	2.428
3	UK	10,963	210,147	19.169	163	87	352	807	67,886,011	16.149	30.956
4	Germany	9,278	143,263	15.441	128	47	193	538	83,783,942	11.074	17.099
5	France	9,311	130,774	14.045	122	41	174	468	65,273,511	14.265	20.035
6	Canada	6,630	113,062	17.053	123	36	161	458	37,742,154	17.567	29.956
7	Australia	4,986	108,838	21.829	115	30	152	422	25,499,884	19.553	42.682
8	Italy	7,297	106,381	14.579	111	29	136	383	60,461,826	12.069	17.595
9	Spain	6,726	93,210	13.858	107	29	115	316	46,754,778	14.386	19.936
10	India	5,721	90,005	15.732	94	21	87	232	1,380,004,385	0.415	0.652
11	Israel	3,355	64,180	19.130	104	31	105	273	8,655,535	38.761	74.149
12	Netherlands	2,993	56,910	19.014	93	27	88	209	17,134,872	17.467	33.213
13	Japan	4,438	53,288	12.007	84	15	63	210	126,476,461	3.509	4.213
14	Switzerland	2,019	53,164	26.332	91	26	77	189	8,654,622	23.329	61.428
15	South Korea	4,417	49,368	11.177	82	12	64	166	51,269,185	8.615	9.629
16	Singapore	2,401	49,234	20.506	90	13	74	208	5,850,342	41.040	84.156
17	Belgium	1,924	36,480	18.960	78	16	57	141	11,589,623	16.601	31.476
18	Austria	1,987	30,950	15.576	67	12	36	113	9,006,398	22.062	34.364
19	Poland	2,049	29,713	14.501	66	11	43	110	37,846,611	5.414	7.851
20	Greece	1,897	27,596	14.547	67	6	35	111	10,423,054	18.200	26.476
21	Brazil	2,298	25,665	11.168	61	5	30	82	212,559,417	1.081	1.207
22	Sweden	1,674	24,179	14.444	63	9	26	84	10,099,265	16.575	23.941
23	Czech Republic	1,443	23,330	16.168	58	7	16	73	10,708,981	13.475	21.785
24	Finland	1,370	22,776	16.625	62	14	41	88	5,540,720	24.726	41.107
25	Iran	2,204	21,299	9.664	57	5	28	69	83,992,949	2.624	2.536
26	Portugal	1,275	17,724	13.901	55	3	22	63	10,196,709	12.504	17.382
27	Turkey	1,386	16,829	12.142	56	1	16	69	84,339,067	1.643	1.995
28	Denmark	1,105	16,336	14.784	56	5	21	70	5,792,202	19.077	28.203
29	Saudi Arabia	1,116	14,137	12.668	54	2	20	65	34,813,871	3.206	4.061
30	Russia	3,561	13,275	3.728	38	0	6	25	145,934,462	2.440	0.910

Source: Own elaboration. Abbreviations are available in Table 2.

China is the leading country. It is followed by China, the second-most-productive country in Cybernetics, Hardware Architecture, Interdisciplinary Applications, Software Engineering, and Theory Methods. Third, we have the United Kingdom, which is the third-most-productive country in all areas, except for Information Systems and Hardware and Architecture. In fourth place is Germany, the third-most-productive country in Software Engineering, the fourth most productive country in Interdisciplinary Applications and the fifth one in Cybernetics and Theory and Methods. It is followed by France, the fifth-most-productive country in Artificial Intelligence, Interdisciplinary Applications, and Theory and Methods.

When we consider the population, the results are very different. The most productive countries are the following: Singapore, Slovenia, Finland, Israel, and Switzerland. Singapore is the most productive in Artificial Intelligence, Hardware Architecture, Information Systems, and Theory and Methods. Norway stands at the head of Cybernetics. Slovenia is the most productive country in Interdisciplinary Applications, and the second one in Artificial Intelligence and Cybernetics. Notice that Luxembourg is the second most productive country in Software Engineering and is the only category where this country appears.

The ratio of citations per documents yields quite different data compared to those previously mentioned. In this case, Sweden (first one only in global ranking), Switzerland (first one in Artificial Intelligence, Cybernetics, Interdisciplinary Applications and Theory and Methods), the United States (first place in Information Systems, and second one in Cybernetics, Hardware and Architecture, Software Engineering and Theory and Methods), the Netherlands (second one in Interdisciplinary Applications, third place in Information Systems, and fifth one in Theory and Methods), and Israel (first one in Hardware and Architecture and Interdisciplinary Applications) stand out.

Finally, regarding the rankings of documents that obtain thresholds of 250, 100 and 50 citations, the most important countries are the United States, China, the United Kingdom, Germany, and Canada.

The results also indicate that Artificial Intelligence is the most influential category, although Information

Systems is the largest category in terms of the number of papers. Focusing on countries, 46 countries have a presence in all the computer science areas, whereas only seven countries have a presence in a single ranking. The general profile of countries in computer science research indicates that European countries, English-speaking countries, and those with high incomes are the ones that are more important in this field. This paper also concludes that the research in computer science field is not exclusively for English-speaking countries; rather, Arabic- and Spanish-speaking countries are also productive. There is also deep research in computer science in middle Asian countries and South American ones.

It is worth noting that this bibliometric overview provides a general picture of state-of-the-art computer science research in recent decades according to the research in the Web of Science. With these findings, researchers can make informed decisions regarding their research directions in terms of identifying top countries and choosing research exchange platforms.

This study has several limitations. First, this study only accounted for journals indexed in WoS without considering other databases. Second, WoS has several limitations when classifying bibliographic material that should also be considered in this article [24]. Third, many other issues may affect research in this field, including open access and electronic journals.

Acknowledgements

Support from the Chilean Government through the Fondecyt Regular program (project number 1160286) is gratefully acknowledged.

Supplementary Material

The supplementary material is available in the electronic version of this article: https://dx.doi.org/10.3233/JIFS-189199.

References

[1] S. Alonso, F.J. Cabrerizo, E. Herrera-Viedma and F. Herrera, H-index: A review focused on its variants, computation, and standardization for different scientific fields, *J Informetrics* **3**(4) (2009), 273–289.

[2] A.U. Aydinoglu and Z. Taskin, Origins of life research: a bibliometric approach, *Origins of Life and Evolution of Biospheres* **48**(1) (2018), 55–71.

[3] C. Bergstrom, Eigenfactor: Measuring the value and prestige of scholarly journals, *College & Research Libraries News* **68**(5) (2007), 314–316.

[4] F. Blanco-Mesa, J.M. Merigó and A.M. Gil-Lafuente, Fuzzy decision making: a bibliometric-based review, *J Intell Fuzzy Syst* **32**(3) (2017), 2033–2050.

[5] F. Blanco-Mesa, E. León-Castro and J.M. Merigó, A bibliometric analysis of aggregation operators, *Applied Soft Computing* **81** (2019), 105488.

[6] C. Cancino, J.M. Merigó, F. Coronado, Y. Dessouky and M. Dessouky, Forty years of Computers and Industrial Engineering: a bibliometric analysis, *Comput Ind Eng* **113** (2017), 614–629.

[7] C. Choppy, J. van Leeuwen, B. Meyer and J. Staunstrup, Research evaluation for computer science, *Communications of the ACM* **52**(4) (2009), 31–34.

[8] M. Franceschet, A comparison of bibliometric indicators for computer science scholars and journals on Web of Science and Google Scholar, *Scientometrics* **83**(1) (2010), 243–258.

[9] F. Franceschini and D. Maisano, Sub-field normalization of the IEEE scientific journals based on their connection with technical societies, *J Informetrics* **8**(3) (2014), 508–533.

[10] E. Garfield, The history and meaning of the journal impact factor, *JAMA J American Medical Association* **295**(1) (2006), 90–93.

[11] M. Gaviria-Marín, J.M. Merigó and S. Popa, Twenty years of the Journal of Knowledge Management: A bibliometric analysis, *J Knowl Manag* **22**(8) (2018), 1655–1687.

[12] D. Godoy, A. Zunino and C. Mateos, Publication practices in the Argentinean computer science community: a bibliometric perspective, *Scientometrics* **102**(2) (2015), 1795–1814.

[13] B. Gonzalez-Pereira, V.P. Guerrero-Bote and F. Moya-Anegon, A new approach to the metric of journals? Scientific prestige: The SJR indicator, *J Informetrics* **4**(3) (2010), 379–391.

[14] X. Gu and K. Blackmore, Characterisation of academic journals in the digital age, *Scientometrics* **110**(3) (2017), 1333–1350.

[15] J.E. Hirsch, An index to quantify an individual's scientific research output, *Proc Natl Acad Sci U.S.A.* **102**(46) (2005), 16599–16572.

[16] Q.F. Huang and Y.Q. Lu, Urban heat island research from 1991 to 2015: a bibliometric analysis, *Theoretical and Applied Climatology* **131**(3–4) (2018), 1055–1067.

[17] S. Laengle, J.M. Merigó, J. Miranda, R. Slowinski, I. Bomze, E. Borgonovo, R.G. Dyson, J.F. Oliveira and R. Teunter, Forty years of European Journal of Operation Research: a bibliometric overview, *Eur J Oper Res* **262**(3) (2017), 803–816.

[18] S. Laengle, N.M. Modak, J.M. Merigó and G. Zurita, Twenty-five years of Group Decision and Negotiation: A bibliometric overview, *Group Dec Negot* **27**(4) (2018), 505–542.

[19] H. Landström, G. Harirchi and F. Aström, Entrepreneurship: Exploring the knowledge base, *Research Policy* **41**(7) (2012), 1154–1181.

[20] X.Y. Leung, J. Sun and B. Bai, Bibliometrics of social media research: A co-citation and co-word analysis, *Int J Hospitality Management* **66** (2017), 35–45.

[21] M. Mabe, The growth and number of journals, *Serials* **16**(2) (2003), 191–197.

[22] F.J. Martínez-López, J.M. Merigó, L. Valenzuela and C. Nicolás, Fifty years of the European Journal of Marketing: A bibliometric analysis, *Eur J Marketing* **52**(1/2) (2018), 439–468.

[23] J.M. Merigó, F. Blanco-Mesa, A.M. Gil-Lafuente and R.R. Yager, Thirty years of the International Journal of Intelligent Systems: a bibliometric review, *Int J Intell Sys* **32**(5) (2017), 526–554.

[24] J.M. Merigó, A.M. Gil-Lafuente and R.R. Yager, An overview of fuzzy research with bibliometric indicators, *Appl Soft Comput* **27** (2015), 420–433.

[25] J.M. Merigó, W. Pedrycz, R. Weber and C.D.L. Sotta, Fifty years of Information Sciences: a bibliometric overview, *Inf Sci* **432** (2018), 245–268.

[26] J.M. Merigó and J.B. Yang, A bibliometric overview of operations research and management science, *Omega* **73** (2017), 37–48.

[27] H.F. Moed, Measuring contextual citation impact of scientific journals, *J Informetrics* **4**(3) (2010), 265–277.

[28] J. Niu, W. Tang, F. Xu, X. Zhou and T. Song, Global research on artificial intelligence from 1990–2014: spatially-explicit bibliometric analysis, *ISPR Int J Geo-Information* **5**(5) (2016), 66.

[29] A. Pritchard, Statistical bibliography or bibliometrics? *J Documentation* **25** (1969), 348–349.

[30] V. Singh, A. Perdigones, J.L. García, I. Cañas-Guerrero and F.R. Mazarrón, Analysis of worldwide research in the field of cybernetics during 1997–2011, *Biological Cybernetics* **108** (2014), 757–776.

[31] V.K. Singh, A. Uddin, D. Pinto and I. Olmos, Computer science research: the top 100 institutions in India and in the World, *Scientometrics* **104**(2) (2015), 529–553.

[32] A. Trianni, J.M. Merigo and P. Bertoldi, Ten years of Energy Efficiency: a bibliometric analysis, *Energy Efficiency* **11** (2018), 1917–1939.

[33] C.F. Tsai, Citation impact analysis of top rated computer science journals and their rankings, *J Informetrics* **8**(2) (2014), 318–328.

[34] A. Tur-Porcar, A. Mas-Tur, J.M. Merigó, N. Roig-Tierno and J. Watt, A bibliometric history of the Journal of Psychology between 1936 and 2015, *J Psyc* **152**(4) (2018), 199–225.

[35] A. Uddin, V.K. Singh, D. Pinto and I. Olmos, Scientometric mapping of computer science research in Mexico, *Scientometrics* **105**(1) (2015), 97–114.

[36] L. Valenzuela, J.M. Merigó, W. Johnston, C. Nicolas and F. Jaramillo, Thirty years of the Journal of Business & Industrial Marketing: A bibliometric analysis, *J Bus Ind Mark* **32**(1) (2017), 1–18.

[37] W. Wang, S. Laengle, J.M. Merigó, D. Yu, E.H. Viedma, M.J. Cobo and B.B. Meunier, A bibliometric analysis of the first twenty-five years of the Int. J. Uncertainty, Fuzziness and Knowledge-Based Systems, *Int. J. Uncertainty Fuzziness Knowl.-Based Syst.* **26**(2) (2018), 169–193.

[38] D. Yu, D.F. Li, J.M. Merigó and L. Fang, Mapping development of linguistic decision making studies, *J. Intell. Fuzzy Syst.* **30**(5) (2016), 2727–2736.

[39] D. Yu and H.C. Liao, Visualization and quantitative research on intuitionistic fuzzy studies, *J. Intell. Fuzzy Syst.* **30**(6) (2016), 3653–3663.