



Bibliometric analysis of CiteSeer data for countries

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ABSTRACT

This article describes the results of our analysis of the data from the CiteSeer digital library. First, we examined the data from the point of view of source top-level Internet domains from which the data were collected. Second, we measured country shares in publications indexed by CiteSeer and compared them to those based on mainstream bibliographic data from the Web of Science and Scopus. And third, we concentrated on analyzing publications and their citations aggregated by countries. This way, we generated rankings of the most influential countries in computer science using several non-recursive as well as recursive methods such as citation counts or PageRank. We conclude that even if East Asian countries are underrepresented in CiteSeer, its data may well be used along with other conventional bibliographic databases for comparing the computer science research productivity and performance of countries.

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1. Introduction

CiteSeer (CiteSeer) is a vast free Web digital library and search engine of mainly computer science papers that have been automatically acquired from various Web sites, stored, and analyzed to allow for searching and exploring its bibliographic data. Despite its free on-line as well as off-line availability and well structured data, it has been relatively rarely used in bibliometric studies particularly due to fears of incomplete and erroneous machine-generated data. We refer to the work by Fiala (2011) where a detailed overview of CiteSeer's features in the context of other established bibliographic databases is given.

The purpose of this study is to show: (a) where CiteSeer has got its data (i.e. which Web domains it has visited to obtain them), (b) which countries have contributed most to its digital library (in terms of the number of papers published by authors from these countries), and (c) which countries have the most influence (in terms of citedness of "their" publications). We have thoroughly analyzed the CiteSeer data file from December 13, 2005 and have made a quick look at the newer data provided by CiteSeer^x (CiteSeer^x) which replaced CiteSeer in April 2010 but is still a beta version at the time of writing this article (May 2011).

2. Related work

There have been a number of studies of research productivity (publications) and impact (citations) at the level of countries in recent years. There is a growing need for such scientometric indicators because they often reflect the quality of science policy in a specific country and may have influence on changes in science funding. From the many research papers

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discussing this topic, let us mention just one of the most recent by [Albarrán, Crespo, Ortuño, and Ruiz-Castillo \(2010\)](#), which compares the United States to the European Union in a detailed way in various fields of science.

While quite a lot of research efforts have been devoted to bibliometrics of chemistry, biology, or humanities, relatively few scientometric studies have been concerned with the field of computer science. [Bakri and Willett \(2011\)](#) measure the performance of computer science research in Malaysia and [Gupta, Kshitij, and Verma \(2011\)](#) analyze the research output of Indian computer science. [Wainer, Xavier, and Bezerra \(2009\)](#) compared the Brazilian computer science production to twelve other countries. [Ma, Ni, and Qiu \(2008\)](#) did not limit their analysis to a particular country but evaluated the computer science research performance of universities around the globe and [Guan and Ma \(2004\)](#) evaluated China and five other countries. Different sources of bibliographic data for the scientometric evaluation of computer science publications were examined by [Bar-Ilan \(2010\)](#) and by [Franceschet \(2010a, 2010b\)](#). The latter author also presents an overview of literature comparing citation data from various data sources for a specific scientific field. Furthermore, [Franceschet \(2010b\)](#) investigated the influence of computer science journal and conference papers on the scientific community.

Unlike our paper, most of the articles above have mainly exploited the well-known and manually-maintained bibliographic database Web of Science ([Web of Science](#)) or its variants. As far as CiteSeer as a data source is concerned, some researchers have already used it for bibliometric purposes: [Zhou, Councill, Zha, and Giles \(2007\)](#) explored CiteSeer documents to discover temporal communities of collaborating authors in the domains of databases and machine learning. On the other hand, [Hopcroft, Khan, Kulis, and Selman \(2004\)](#) tracked evolving communities in the whole CiteSeer paper citation graph. [An, Janssen, and Milios \(2004\)](#) conducted a component analysis of the CiteSeer paper citation graph in several research domains and CiteSeer^x data were used by [Wu and Koh \(2010\)](#) in order to enhance collaborative networks with topic information. [Zhao and Strotmann \(2007\)](#) and [Zhao and Logan \(2002\)](#) analyzed co-citations in CiteSeer documents in the XML research field and a similar study for computer graphics was reported by [Chen \(2000\)](#). [Bar-Ilan \(2006\)](#) used CiteSeer data for a citation analysis of the works of a famous mathematician. A kind of citation analysis for acknowledgements was also performed by [Giles and Councill \(2004\)](#). [Feitelson and Yovel \(2004\)](#) examined citation ranking lists obtained from CiteSeer and predicted future rankings of authors.

Our study is the first of its kind that attempts to measure the productivity and impact of computer science research conducted by countries by analyzing CiteSeer data.

3. Data

The last CiteSeer data originate from December 2005 and they contain roughly 717 thousand publications with 1.8 million references within CiteSeer. On the other hand, CiteSeer^x (data from March 2011) provides more than 1.3 million publications with almost 15 million references within CiteSeer^x. This means that the citation graph with publications as nodes and references as edges has become much denser over the past 6 years – the mean number of references in a publication increased from 2.5 in 2005 to 11.2 in 2011.

Let us have a look at a few obvious differences between CiteSeer (CS)/CiteSeer^x (CS^x) and Web of Science/Scopus ([Scopus](#)) – two well-known databases of scientific literature. Both CiteSeer and CiteSeer^x collect (or collected) its data in the same way: they crawl the Web starting from some seed pages submitted by their engineers or by individual users (authors) and pick up freely accessible documents (mostly PDF or PostScript files) that have the potential to be research papers in computer science, mathematics, or related fields. Web crawling as well as information extraction (titles, author names, references, etc.) occurs automatically, without human intervention. The contents of CiteSeer and CiteSeer^x depend generally on the content and structure of the Web. On the other hand, both Web of Science and Scopus use a great deal of human labor to receive publications (mainly journal issues and conference proceedings) and to index them. Unlike CiteSeer and CiteSeer^x, WoS and Scopus cover all scientific fields. Which publication sources are indexed and which are not is decided by the editorial boards of both “human-made” databases. Another big difference between CiteSeer and CiteSeer^x on one side and WoS and Scopus on the other is that the first two are free whereas the latter two are subscription-based.

4. Methods

4.1. Data collection

Data collection methods were different for CiteSeer and for CiteSeer^x. For CiteSeer, there was a single archive data file created in December 2005 (the most recent CiteSeer data) that we merely downloaded from the CiteSeer Web site and unpacked into 2 GB of 72 XML-like files. As for CiteSeer^x, we were forced to use one of the harvesting tools referenced on its Web site to gain off-line access to its current repository. The harvest itself took a few days in March 2011 and resulted in a regular 3.7 GB XML file which we further split up into 73 files to process them more smoothly in main memory. We developed software¹ that parsed the data files and stored information about publications, authors, and citations in a relational database. We were then able to query the database and obtain the information presented in the following sections. The software also had capabilities to compute more complex values such as HITS and PageRank.

¹ <http://textmining.zcu.cz/downloads/sciento.php>.

4.2. Internet domains and countries

Gathering statistics about Internet top-level domains (TLD) is quite smooth and accurate given that the “source” property for each document is almost always present and error free. The situation gets considerably worse when we try to assemble similar statistical data for the distribution of countries whose authors produced the publications collected by CiteSeer. As far as CiteSeer^X is concerned, unfortunately, it does not provide any information on the addresses or affiliations of the authors of its publications – not only for “new” publications, but also for “old” publications for which this information is present in CiteSeer. Therefore, we could not use CiteSeer^X data for our experiments with countries. Let us hope that future versions of CiteSeer^X (the current one is still a beta) will have such information included.

4.3. Missing data and name unification

In CiteSeer, there is a problem with missing data. For almost each document, there are authors assigned to it but only for some of the authors there is also an address affiliated with him/her. Strictly said, from the total of 1.66 million authors (without any name unification or disambiguation), we had no address information at our disposal for about 690 thousand or 42% of them, let alone the accuracy of such information.

Thus, to obtain the data shown later in Fig. 2, we proceeded in the following way: We discarded publications without any address information for any of its authors. This resulted in only 439 thousand being kept. (For these publications, one author at least had some address information included.) Then, we tried to unify country names used in the addresses. This task consisted in obtaining a list of countries and territories owning a top-level Internet domain. After some cleansing, 243 countries or territories were left. Next, we attempted to unify country names by replacing common synonymic variants of each of those 243 countries with one standard name.

For instance, in the case of the United States of America, we had to count in names like “United States”, “U.S.A.”, “U.S.A”, “U.S.”, “USA”, or “US”. Since US postal addresses often do not contain any mention of “USA” or its variants and only display the name or abbreviation of a federal state such as “California” or “CA”, we also needed to take this into account and counted such occurrences as “USA”. Other types of unification included considering often independently appearing entities such as England, Scotland, Wales and Northern Ireland as one country (United Kingdom) or, in contrast, keeping territories of one country separate such as Hong Kong, Taiwan, and Macau from China or Reunion and Martinique from France. Finally, we processed international postal country codes in the addresses as well, thus yielding Czech Republic for an address “CZ-30416” with respect to the prefix “CZ-” as an example.

4.4. Comparison with the Web of Science and Scopus

Since the CiteSeer data we examined were from December 2005, we restricted our analysis to a 10-year period from 1996 to 2005. This decade is the most probable one, in which CiteSeer was collecting its documents. Moreover, Scopus itself does not generally capture citations to documents published before 1996, which is also a good reason for 1996 as a decade’s start with regard to possible future comparisons of citations. In September 2010, we were querying on-line Web services of both WoS and Scopus and generated the rankings in Tables 3 and 4. As for WoS, we opted to limit our search to the “Science Citation Index Expanded” database, to the “article” document type, and to the publications from the journals included in the seven computer science subject categories of the Journal Citation Reports[®] Science Edition 2009. In this way, we arrived at the total of 148 838 publications, which is 100% for the relative shares in Table 3. As far as Scopus is concerned, querying was easier in that the subject area (computer science) could be specified directly in the query and the exact results number was always disclosed. The final 325 614 “article” documents form 100% for the relative shares in Table 4. Due to the search limits of both WoS and Scopus, it was sometimes necessary to split up “big” queries into subqueries and to combine their results.

Alternatively, WoS as well as Scopus provide programming interfaces that enable submitting queries and obtaining results without needing to interact with their Web front-ends. However, the basic APIs included in the subscription do have queries and results restrictions that are similar to those on their Web sites.

4.5. Citations and recursive indicators

In addition to measuring shares of individual countries in the publications indexed by CiteSeer, we wished to determine the influence of countries by examining citations they receive. Thus, we derived a citation graph of countries from the citation graph of publications. In the directed publication citation graph, there were 717 thousand nodes (publications) and 1.76 million edges (citations between publications). This accounts for roughly 2.45 citations per paper so, obviously, many citations (or references) are missing in CiteSeer. Let us recall that addresses of publications’ authors were normalized by the approach described earlier. We aggregated citations by the country of the source and target publication. If there were more countries associated with a publication, a couple of citations came into being. We removed self-citations of countries as well.

Besides first-order methods such as in-degree and citations, there are recursive techniques as well that not only count citations but take also into account whether the citing node itself is frequently cited. Some of these methods are HITS introduced by Kleinberg (1999), PageRank defined by Brin and Page (1998), or weighted PageRank (e.g., Fiala, Rousselot, & Ježek,

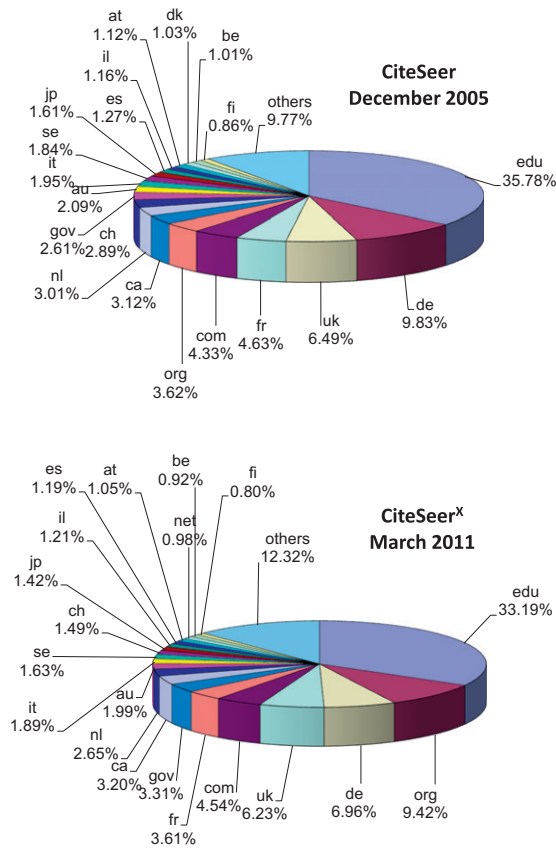


Fig. 1. Shares of Internet domains from which CiteSeer and CiteSeer^X documents have been collected.

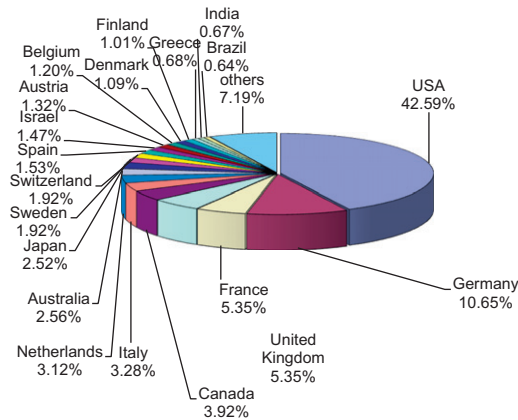


Fig. 2. Shares of countries to which publications are assigned in CiteSeer.

2008). We applied these methods to the normalized country citation graph from CiteSeer and present the country rankings obtained in Table 6.

5. Results and discussion

5.1. Internet domains

One of the properties of each document item indexed by CiteSeer is its source. This is the URL (a Web page) from which the document has originally been downloaded. We were interested in the distribution of Internet top-level domains (TLD)

Table 1
Top 100 Internet top-level domains (TLD) by publications in CiteSeer compared to CiteSeer^x.

Dec 2005				March 2011			Dec 2005				March 2011		
No.	TLD	# Pub.	%	No.	# Pub.	%	No.	TLD	# Pub.	%	No.	# Pub.	%
1	edu	256433	35.78	1	442756	33.19	51	ua	273	0.04	68	280	0.02
2	de	70446	9.83	3	92821	6.96	52	ar	226	0.03	52	739	0.06
3	uk	46544	6.49	4	83049	6.23	53	hr	197	0.03	55	546	0.04
4	fr	33172	4.63	6	48190	3.61	54	cy	175	0.02	63	338	0.03
5	com	31051	4.33	5	60570	4.54	55	yu	165	0.02	58	488	0.04
6	org	25922	3.62	2	125650	9.42	56	uy	146	0.02	69	175	0.01
7	ca	22368	3.12	8	42671	3.20	57	ee	137	0.02	56	536	0.04
8	nl	21544	3.01	9	35411	2.65	58	ir	135	0.02	54	548	0.04
9	ch	20686	2.89	13	19908	1.49	59	bg	116	0.02	60	369	0.03
10	gov	18694	2.61	7	44179	3.31	60	co	109	0.02	81	79	0.01
11	au	14976	2.09	10	26547	1.99	61	ve	105	0.01	72	123	0.01
12	it	13976	1.95	11	25188	1.89	62	info	91	0.01	41	2507	0.19
13	se	13178	1.84	12	21721	1.63	63	lv	65	0.01	71	155	0.01
14	jp	11522	1.61	14	18911	1.42	64	my	65	0.01	59	462	0.03
15	es	9092	1.27	16	15851	1.19	65	py	54	0.01	169	0	0.00
16	il	8287	1.16	15	16162	1.21	66	to	54	0.01	66	285	0.02
17	at	8056	1.12	17	14013	1.05	67	is	52	0.01	67	284	0.02
18	dk	7360	1.03	21	10250	0.77	68	lt	52	0.01	53	581	0.04
19	be	7270	1.01	19	12261	0.92	69	ps	51	0.01	65	286	0.02
20	fi	6145	0.86	20	10705	0.80	70	lu	46	0.01	75	109	0.01
21	kr	4791	0.67	29	6404	0.48	71	mt	30	0.00	77	106	0.01
22	gr	4336	0.60	22	9077	0.68	72	mk	27	0.00	87	50	0.00
23	pt	4229	0.59	24	7604	0.57	73	lb	26	0.00	72	123	0.01
24	no	3977	0.55	27	6697	0.50	74	ma	26	0.00	79	95	0.01
25	br	3973	0.55	31	6109	0.46	75	ph	25	0.00	76	107	0.01
26	cz	3844	0.54	30	6305	0.47	76	gb	24	0.00	93	24	0.00
27	i.e.	3522	0.49	26	6708	0.50	77	nu	21	0.00	80	91	0.01
28	hk	3470	0.48	23	7759	0.58	78	et	18	0.00	106	14	0.00
29	net	2847	0.40	18	13091	0.98	79	aero	15	0.00	109	11	0.00
30	mil	2527	0.35	35	4054	0.30	80	fm	15	0.00	62	345	0.03
31	nz	2427	0.34	28	6448	0.48	81	id	15	0.00	78	96	0.01
32	pl	2202	0.31	34	4417	0.33	82	sa	15	0.00	57	514	0.04
33	tw	2056	0.29	33	4981	0.37	83	biz	10	0.00	88	49	0.00
34	mx	1978	0.28	42	2301	0.17	84	cu	10	0.00	98	20	0.00
35	hu	1905	0.27	37	3805	0.29	85	name	10	0.00	64	290	0.02
36	sg	1725	0.24	32	5572	0.42	86	rs	10	0.00	102	15	0.00
37	in	1423	0.20	25	7342	0.55	87	tc	10	0.00	99	19	0.00
38	cn	1265	0.18	38	3396	0.25	88	ws	9	0.00	84	65	0.00
39	tr	1208	0.17	40	2800	0.21	89	mu	6	0.00	113	9	0.00
40	ru	1176	0.16	44	1892	0.14	90	mo	5	0.00	85	61	0.00
41	cl	1054	0.15	47	1657	0.12	91	om	5	0.00	122	5	0.00
42	si	801	0.11	43	1900	0.14	92	li	4	0.00	113	9	0.00
43	za	785	0.11	45	1735	0.13	93	tv	4	0.00	96	21	0.00
44	int	621	0.09	39	3256	0.24	94	ac	3	0.00	110	10	0.00
45	th	474	0.07	51	844	0.06	95	af	3	0.00	126	4	0.00
46	us	462	0.06	36	3954	0.30	96	cx	3	0.00	100	18	0.00
47	sk	459	0.06	49	1439	0.11	97	pg	3	0.00	169	0	0.00
48	su	447	0.06	61	353	0.03	98	ae	2	0.00	86	52	0.00
49	cc	333	0.05	48	1630	0.12	99	am	2	0.00	119	7	0.00
50	ro	277	0.04	50	1014	0.08	100	ge	2	0.00	102	15	0.00

among the sources of CiteSeer documents. This would reveal what regions of the Web the CiteSeer Web crawler has visited and to what extent. It might also help explain a possible bias in publication and citations shares of individual countries discovered later.

Fig. 1 shows the shares of top 20 top-level Internet domains as sources of CiteSeer and CiteSeer^x documents. The charts are quite similar – approximately one third of all publications originate from .edu servers, followed by .de, .uk, .fr, and .com with the most notable change for .org, which grew from 3.62% to 9.42% between 2005 and 2011. Although .edu, .com, and .org domains do not necessarily mean US Web sites, we shall not be too far from the truth if we count them along with .gov as US sites and claim that about a half of all CiteSeer documents have been gathered in the United States with a small increase by several percentage points from 2005 to 2011. In 2005, only 25 documents had no source URL affiliated with them and they are included in those almost 10% of “other” domains. In 2011, this number is considerably higher – almost 17 thousand – and the share of “other” domains is as much as 12%. A complete list of the top 100 CiteSeer source domains is available in Table 1 with their respective ranks and shares in CiteSeer^x. After a quick look at the table, we may notice that a couple of non-country TLDs have significantly increased their shares such as .org (moving from rank 6 to rank 2), .net (from 29 to 18), or .info

(from 62 to 41) while the main country-code TLDs remain relatively stable or even slightly decline. There is one remarkable exception, *.in*, which increases its rank from 37 to 25 and its share from 0.20% to 0.55% between the years 2005 and 2011. In this context, it is interesting to see that the position of *.cn* (38) remains unchanged in both CiteSeer and CiteSeer^x.

Nowadays, most open access repositories are located within North America and Europe (Repository66) and, therefore, it is logical that even Asian researchers might prefer placing their manuscripts in the repositories of these regions, which further increases the prevalence of American and European top-level Internet domains crawled by CiteSeer.

5.2. Countries

After unifying country names in the available addresses as described in Section 4.3, we tried to assign all 439 thousand publications to one or more country depending on how many authors from which countries they had. About 25 thousand publications could not be assigned to any country, i.e. it was impossible to make use of the information in their address field to identify a standard country by the above approach. Thus, only 414 thousand documents (58% of 717 thousand) were finally assigned to one or more country. We counted the assignments to countries and found out country shares that are

Table 2

Top 100 countries by publications in CiteSeer.

Rank	Country	Public.	Share (%)	Rank	Country	Public.	Share (%)
1	USA	191363	26.70	51	Belarus	119	0.02
2	Germany	47866	6.68	52	Venezuela	114	0.02
3	France	24052	3.36	53	Egypt	107	0.01
4	United Kingdom	24042	3.35	54	Latvia	102	0.01
5	Canada	17630	2.46	55	Uruguay	96	0.01
6	Italy	14718	2.05	56	Serbia and Mont.	94	0.01
7	Netherlands	14022	1.96	57	Lithuania	93	0.01
8	Australia	11496	1.60	58	Lebanon	66	0.01
9	Japan	11328	1.58	59	Tunisia	66	0.01
10	Sweden	8639	1.21	60	Colombia	60	0.01
11	Switzerland	8611	1.20	61	Malta	60	0.01
12	Spain	6876	0.96	62	Armenia	55	0.01
13	Israel	6616	0.92	63	Iceland	55	0.01
14	Austria	5934	0.83	64	Panama	53	0.01
15	Belgium	5411	0.75	65	Vietnam	44	0.01
16	Denmark	4882	0.68	66	Cuba	42	0.01
17	Finland	4533	0.63	67	Morocco	39	0.01
18	Greece	3038	0.42	68	Macau	37	0.01
19	India	3002	0.42	69	Pakistan	36	0.01
20	Brazil	2889	0.40	70	Indonesia	34	0.00
21	Portugal	2650	0.37	71	Saudi Arabia	34	0.00
22	Russia	2351	0.33	72	Puerto Rico	32	0.00
23	Hong Kong	2238	0.31	73	Philippines	31	0.00
24	Norway	2215	0.31	74	Kuwait	30	0.00
25	Singapore	1897	0.26	75	Algeria	25	0.00
26	Taiwan	1808	0.25	76	Bangladesh	24	0.00
27	New Zealand	1703	0.24	77	Costa Rica	23	0.00
28	China	1600	0.22	78	Jordan	21	0.00
29	Poland	1564	0.22	79	Kenya	14	0.00
30	Czech Republic	1453	0.20	80	Liechtenstein	14	0.00
31	South Korea	1450	0.20	81	Macedonia	14	0.00
32	Hungary	1423	0.20	82	Nigeria	14	0.00
33	Ireland	1366	0.19	83	Moldova	13	0.00
34	Mexico	1071	0.15	84	Oman	11	0.00
35	Turkey	775	0.11	85	Cameroon	9	0.00
36	Slovenia	659	0.09	86	Jamaica	9	0.00
37	Chile	489	0.07	87	Martinique	9	0.00
38	South Africa	472	0.07	88	Netherlands Antilles	9	0.00
39	Romania	450	0.06	89	Sri Lanka	9	0.00
40	Argentina	445	0.06	90	Reunion	8	0.00
41	Thailand	335	0.05	91	United Arab Emirates	8	0.00
42	Ukraine	306	0.04	92	Uzbekistan	8	0.00
43	Bulgaria	299	0.04	93	Ethiopia	7	0.00
44	Cyprus	285	0.04	94	Vatican	7	0.00
45	Slovakia	250	0.03	95	Bahrain	6	0.00
46	Luxembourg	242	0.03	96	Fiji	6	0.00
47	Iran	215	0.03	97	Guinea	6	0.00
48	Croatia	149	0.02	98	Mozambique	6	0.00
49	Estonia	141	0.02	99	Nicaragua	6	0.00
50	Malaysia	131	0.02	100	Uganda	6	0.00

Table 3

Top 30 computer science countries by Web of Science in 1996–2005.

Rank	Cite-Seer	Country	Publications	Share (%)	Citations	Average citations	<i>h</i> -index
1	1	USA	52579	35.33	904339	17.20	258
2	4	United Kingdom	11515	7.74	160691	13.95	125
3	9	Japan	8902	5.98	72379	8.13	82
4	2	Germany	8554	5.75	114075	13.34	108
5		China	8348	5.61	92050	11.03	86
6	5	Canada	7630	5.13	102609	13.45	105
7	3	France	7159	4.81	97801	13.66	102
8		Taiwan	6690	4.49	66762	9.98	76
9	6	Italy	6587	4.43	76837	11.66	87
10		South Korea	4753	3.19	42720	8.99	65
11	12	Spain	4421	2.97	50272	11.37	76
12	8	Australia	4196	2.82	54625	13.02	82
13	7	Netherlands	3503	2.35	55459	15.83	88
14	19	India	3103	2.08	27613	8.90	55
15	13	Israel	3014	2.03	46385	15.39	82
16		Singapore	2695	1.81	32015	11.88	66
17		Russia	2246	1.51	7879	3.51	33
18	18	Greece	2153	1.45	20283	9.42	50
19	15	Belgium	1849	1.24	29343	15.87	65
20	11	Switzerland	1838	1.23	37542	20.43	78
21	10	Sweden	1766	1.19	23825	13.49	57
22	20	Brazil	1449	0.97	14601	10.08	46
23		Poland	1440	0.97	15948	11.08	50
24	17	Finland	1408	0.95	23137	16.43	59
25	14	Austria	1357	0.91	17065	12.58	51
26		Turkey	1284	0.86	13160	10.25	44
27	16	Denmark	1045	0.70	16645	15.93	53
28		Hong Kong	858	0.58	10909	12.71	47
29		Ireland	806	0.54	8202	10.18	38
30		Hungary	791	0.53	8072	10.20	41

Table 4

Top 30 computer science countries by Scopus in 1996–2005.

Rank	Cite-Seer	Country	Publications	Share (%)	Citations	Average citations	<i>h</i> -index
1	1	USA	87591	26.90	1731096	19.76	360
2		China	26004	7.99	149019	5.73	104
3	4	United Kingdom	21545	6.62	292929	13.60	163
4	9	Japan	21231	6.52	141346	6.66	106
5	2	Germany	18125	5.57	213144	11.76	143
6	3	France	14570	4.47	187746	12.89	136
7	5	Canada	13001	3.99	191347	14.72	135
8	6	Italy	12133	3.73	147608	12.17	117
9		South Korea	10370	3.18	84225	8.12	91
10		Taiwan	10238	3.14	106810	10.43	95
11	12	Spain	8035	2.47	87291	10.86	94
12	8	Australia	7105	2.18	96481	13.58	103
13	19	India	5997	1.84	58432	9.74	80
14	7	Netherlands	5966	1.83	93431	15.66	110
15		Hong Kong	5382	1.65	78625	14.61	94
16		Russia	5177	1.59	16783	3.24	45
17	13	Israel	4767	1.46	81874	17.18	108
18		Singapore	4230	1.30	51347	12.14	79
19	18	Greece	3932	1.21	38669	9.83	66
20	10	Sweden	3916	1.20	69242	17.68	85
21	11	Switzerland	3618	1.11	75824	20.96	111
22	15	Belgium	3479	1.07	55409	15.93	86
23		Poland	3165	0.97	25992	8.21	57
24	17	Finland	2867	0.88	37645	13.13	73
25	20	Brazil	2860	0.88	24543	8.58	55
26		Turkey	2496	0.77	23679	9.49	57
27	14	Austria	2371	0.73	27242	11.49	66
28	16	Denmark	1818	0.56	26444	14.55	64
29		Portugal	1527	0.47	15513	10.16	50
30		Hungary	1500	0.46	16459	10.97	50

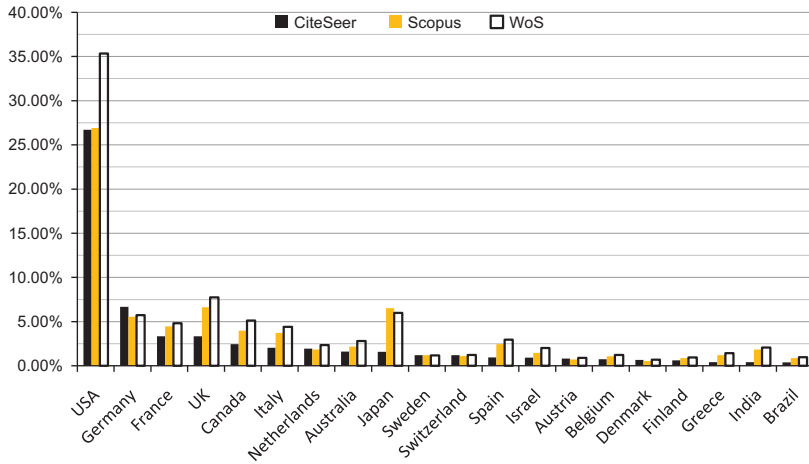


Fig. 3. Publication shares of top 20 CiteSeer countries in Scopus and WoS.

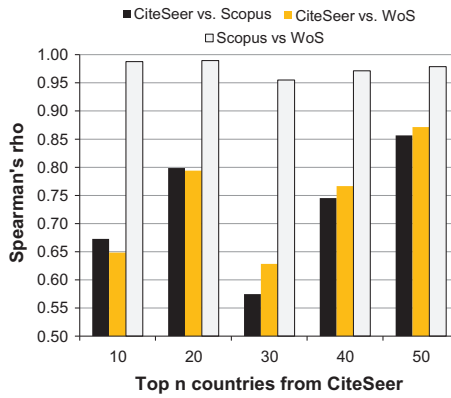


Fig. 4. Correlations of country publication rankings of CiteSeer, Scopus, and WoS.

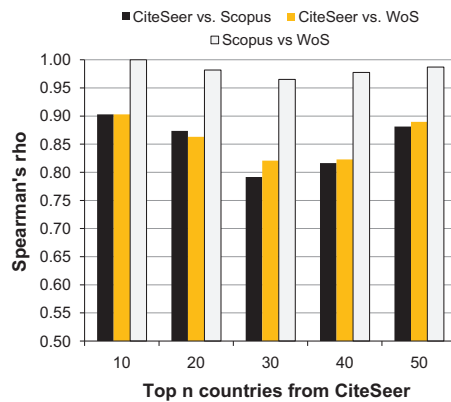


Fig. 5. Correlations of country citation rankings of CiteSeer, Scopus, and WoS.

demonstrated relatively as well as absolutely in Fig. 2 and in Table 2. Note, however, that the relative shares in Fig. 2 differ from those presented in Table 2.

The relative shares in Fig. 2 sum up to 100% constituted by a total of 449 thousand publication-country assignments, which is not equal to 414 thousand publications due to international co-authorships. (Albarrán et al. (2010) call the publication-country assignments “extended articles”.) Even though the number of such assignments is only less than 10% greater

than that of publications, it does not necessarily imply a relatively low number of international publications in CiteSeer. We may rather assume that addresses in international papers are more difficult to be processed by a machine (CiteSeer) and, therefore, they are often missing or erroneous and do not appear in our cleansed data.

In Fig. 2, the top 20 most represented countries take almost 93% of “extended articles”. The first country is the United States with a fourfold greater share (42.59%) than the second most “prolific” country – Germany (10.65%). At the third position, there is a tie between France and the United Kingdom (both 5.35%). As a remarkable point, two developing countries have entered the Top 20 – India and Brazil with shares of 0.67% and 0.64%, respectively. The number (or share) of publications not assigned to any country is not visible in Fig. 2.

The relative shares in Table 2 are smaller than those in Fig. 2 because the base (100%) is much larger – 717 thousand, which is the original number of CiteSeer documents. These relative shares are important for they help us compare CiteSeer publication shares with those from the Web of Science and Scopus where the number of all documents can be determined, but the number of publication-country assignments is unknown. The absolute numbers in Table 2 are the numbers of publications assigned to a country and they were input in Fig. 2. If, hypothetically, each CiteSeer article was assigned to exactly one country, the sum of counts in Table 2 would be approximately 717 thousand and the total share 100% (the rest after rank 100 is negligible). If each document was assigned to two or more countries (i.e. all papers are internationally co-authored), the sum of counts would be more than 717 thousand and the total share more than 100%. A further discussion of the results in Table 2 will follow in the next section along with a comparison to the Web of Science and Scopus.

5.3. Comparison with the Web of Science and Scopus

To get a clue how reliable CiteSeer data are and to see how distant or close to other well-known bibliographic data sources they are, it was necessary to perform a couple of comparisons and measurements. Based on the amount of available

Table 5
Top 80 countries by in-degree and citations in CiteSeer.

In-degree			Citations								
R.	Country	In	R.	Country	In	R.	Country	Cites	R.	Country	Cites
1	USA	98	41	Slovakia	26	1	USA	728289	41	Romania	641
2	Germany	82	42	Chile	24	2	Germany	122389	42	Chile	590
3	United Kingdom	75	43	Jordan	22	3	United Kingdom	89933	43	Jordan	425
4	Canada	74	44	Argentina	21	4	France	82632	44	Slovakia	416
5	France	74	45	Bahrain	21	5	Canada	76148	45	Thailand	409
6	Australia	66	46	South Africa	21	6	Italy	52570	46	South Africa	328
7	Netherlands	66	47	Bulgaria	20	7	Netherlands	42252	47	Venezuela	321
8	Switzerland	66	48	Croatia	18	8	Israel	33701	48	Bahrain	246
9	Italy	64	49	Estonia	18	9	Switzerland	33185	49	Croatia	222
10	Israel	63	50	Venezuela	18	10	Japan	32433	50	Estonia	190
11	Japan	62	51	Uruguay	15	11	Australia	27484	51	Ukraine	183
12	Sweden	62	52	Egypt	14	12	Belgium	21356	52	Bulgaria	179
13	Spain	58	53	Lebanon	14	13	Sweden	21211	53	Uruguay	179
14	Austria	55	54	Serbia & Mt.	14	14	Austria	13975	54	Panama	165
15	Denmark	55	55	Lithuania	13	15	Finland	13953	55	Lebanon	147
16	Finland	54	56	Latvia	12	16	Spain	13543	56	Iceland	141
17	Singapore	53	57	Malta	12	17	Denmark	12744	57	Egypt	138
18	Belgium	52	58	Panama	11	18	India	10882	58	Iran	119
19	Greece	50	59	Belarus	10	19	Greece	7304	59	Lithuania	108
20	India	48	60	Fiji	10	20	Singapore	6165	60	Latvia	103
21	Hong Kong	45	61	Iceland	10	21	Mexico	5618	61	Fiji	97
22	Portugal	45	62	Bangladesh	9	22	Hong Kong	5419	62	Serbia & Mt.	81
23	Russia	45	63	Iran	9	23	Portugal	5398	63	Macau	62
24	Brazil	43	64	Pakistan	8	24	Brazil	5056	64	Belarus	55
25	Taiwan	42	65	Ukraine	8	25	Taiwan	3828	65	Pakistan	54
26	China	40	66	Saudi Arabia	7	26	South Korea	3413	66	Saudi Arabia	50
27	New Zealand	40	67	Moldova	6	27	Russia	3218	67	Liechtenstein	42
28	Poland	40	68	Macau	5	28	Norway	3008	68	Kuwait	40
29	Ireland	39	69	Morocco	5	29	New Zealand	2978	69	Moldova	35
30	Hungary	38	70	Costa Rica	4	30	Ireland	2952	70	Bangladesh	23
31	Mexico	37	71	Kuwait	4	31	Hungary	2816	71	Reunion	21
32	Norway	37	72	Vietnam	4	32	China	2385	72	Vietnam	21
33	Czech Republic	36	73	Armenia	3	33	Poland	1696	73	Costa Rica	18
34	Cyprus	35	74	Colombia	3	34	Slovenia	1389	74	Armenia	16
35	South Korea	34	75	Indonesia	3	35	Cyprus	1162	75	Indonesia	15
36	Turkey	34	76	Tunisia	3	36	Turkey	1089	76	Monaco	14
37	Slovenia	33	77	Antarctica	2	37	Luxembourg	920	77	Morocco	13
38	Luxembourg	29	78	Congo	2	38	Czech Republic	837	78	Tunisia	12
39	Thailand	27	79	Ethiopia	2	39	Argentina	721	79	Antarctica	10
40	Romania	26	80	Jamaica	2	40	Malta	649	80	Colombia	9

Table 6
Top 80 countries by HITS, PageRank and weighted PageRank in CiteSeer.

HITS				PageRank				Weighted PageRank			
R.	Country	R.	Country	R.	Country	R.	Country	R.	Country	R.	Country
1	USA	41	Slovakia	1	USA	41	Thailand	1	USA	41	Romania
2	Germany	42	Chile	2	Canada	42	Chile	2	Germany	42	Chile
3	UK	43	Jordan	3	Germany	43	Jordan	3	UK	43	Malta
4	Canada	44	Argentina	4	UK	44	South Africa	4	France	44	Thailand
5	France	45	Bahrain	5	France	45	Argentina	5	Canada	45	Jordan
6	Netherlands	46	South Africa	6	Israel	46	Bahrain	6	Italy	46	Venezuela
7	Italy	47	Bulgaria	7	Italy	47	Bulgaria	7	Netherlands	47	South Africa
8	Australia	48	Croatia	8	Switzerland	48	Venezuela	8	Israel	48	Bahrain
9	Switzerland	49	Venezuela	9	Netherlands	49	Croatia	9	Japan	49	Croatia
10	Japan	50	Estonia	10	Australia	50	Estonia	10	Switzerland	50	Estonia
11	Sweden	51	Uruguay	11	Japan	51	Uruguay	11	Australia	51	Bulgaria
12	Israel	52	Egypt	12	Sweden	52	Egypt	12	Sweden	52	Panama
13	Spain	53	Lebanon	13	Austria	53	Lebanon	13	Belgium	53	Iceland
14	Finland	54	Serbia & Mt.	14	Spain	54	Serbia & Mt.	14	Austria	54	Lebanon
15	Denmark	55	Lithuania	15	Denmark	55	Lithuania	15	Finland	55	Uruguay
16	Austria	56	Latvia	16	Belgium	56	Latvia	16	Spain	56	Egypt
17	Belgium	57	Malta	17	Finland	57	Malta	17	Denmark	57	Ukraine
18	Singapore	58	Panama	18	Greece	58	Panama	18	India	58	Lithuania
19	Greece	59	Iceland	19	India	59	Iceland	19	Greece	59	Iran
20	India	60	Belarus	20	Singapore	60	Belarus	20	Mexico	60	Fiji
21	Hong Kong	61	Fiji	21	Russia	61	Fiji	21	Singapore	61	Latvia
22	Russia	62	Iran	22	Portugal	62	Iran	22	Hong Kong	62	Serbia & Mt.
23	Portugal	63	Bangladesh	23	Hong Kong	63	Bangladesh	23	Brazil	63	Liechtenstein
24	Taiwan	64	Ukraine	24	Brazil	64	Pakistan	24	Portugal	64	Pakistan
25	Brazil	65	Pakistan	25	New Zealand	65	Ukraine	25	Taiwan	65	Saudi Arabia
26	Ireland	66	Saudi Arabia	26	Taiwan	66	Saudi Arabia	26	New Zealand	66	Belarus
27	Poland	67	Moldova	27	Poland	67	Moldova	27	South Korea	67	Macau
28	China	68	Morocco	28	Ireland	68	Morocco	28	Russia	68	Vietnam
29	New Zealand	69	Macau	29	China	69	Kuwait	29	Norway	69	Kuwait
30	Norway	70	Costa Rica	30	Norway	70	Macau	30	Hungary	70	Moldova
31	Hungary	71	Kuwait	31	Hungary	71	Costa Rica	31	Ireland	71	Monaco
32	Mexico	72	Vietnam	32	Mexico	72	Vietnam	32	China	72	Reunion
33	South Korea	73	Armenia	33	Czech Rep.	73	Armenia	33	Poland	73	Costa Rica
34	Czech Rep.	74	Indonesia	34	Cyprus	74	Indonesia	34	Slovenia	74	Indonesia
35	Turkey	75	Tunisia	35	South Korea	75	Tunisia	35	Cyprus	75	Tunisia
36	Cyprus	76	Colombia	36	Turkey	76	Colombia	36	Turkey	76	Morocco
37	Slovenia	77	Reunion	37	Slovenia	77	Ethiopia	37	Slovakia	77	Armenia
38	Luxembourg	78	Liechtenstein	38	Luxembourg	78	Liechtenstein	38	Czech Rep.	78	Vatican
39	Thailand	79	Neth. Antilles	39	Romania	79	Reunion	39	Luxembourg	79	Bangladesh
40	Romania	80	Ethiopia	40	Slovakia	80	Puerto Rico	40	Argentina	80	Colombia

information on publication shares of countries from the previous section, we decided to compare these country shares to those obtained from the Web of Science and Scopus – two established manually maintained bibliographic databases. The goal was to create rankings of countries by the number of “their” publications in the field of computer science and to compare them to the CiteSeer ranking in Table 2.

In addition to article counts, we also found out numbers of citations to the articles, average citations per article, and *h*-indices as defined by Hirsch (2005) for individual countries. In both Tables 3 and 4, countries are ordered descendingly by the number of publications and the countries from the top 20 CiteSeer countries (see Table 2) are marked with their CiteSeer rank in the second column. When looking at the rankings, we may immediately note that three East Asian countries (mainland China, South Korea, and Taiwan) are under-represented in CiteSeer. Both WoS and Scopus place them in the Top 10 whereas in CiteSeer they are at ranks around 30. The corresponding top-level Internet domains *.cn*, *.kr*, and *.tw* in Table 1 are also relatively lowly ranked, which might suggest that CiteSeer did not crawl these Web regions so extensively as it should have regarding their real scientific productivity in computer science. Otherwise, we cannot see any striking discrepancies between CiteSeer on one side and WoS and Scopus on the other.

Publication shares of the top 20 CiteSeer countries in CiteSeer, WoS, and Scopus are shown in Fig. 3. There are no evident outliers or differences either, except perhaps for a greater USA share in WoS. In Fig. 4, we show Spearman's rank correlation coefficients between the rankings of CiteSeer and Scopus, CiteSeer and WoS, and Scopus and WoS for the top 10, 20, 30, 40, and 50 CiteSeer countries. All the coefficients are significant at the 0.01 level (two-tailed) except those around 0.65 in the top ten, which are significant at the 0.05 level. Not surprisingly, the rankings from Scopus and WoS are always very highly positively correlated (0.96–0.99). But as for CiteSeer, it is also positively correlated with the highest correlation being about 0.86 in the top 50. We may conclude that the ranking by publications from CiteSeer (Table 2) is relevant and quite competitive compared to the rankings from both WoS and Scopus. As there is no simple way of obtaining the total count of citations to all

computer science publications published from 1996 to 2005 from the Web sites of WoS and Scopus, which would be necessary to determine the relative citation shares in Tables 3 and 4, we do not present a comparison plot similar to Fig. 3 for citations. But we do show, in analogy to Fig. 5, how citation-based rankings correlate with each other in Fig. 5. As we can see, the rankings of countries based on citations from CiteSeer correlate quite positively (0.79–0.90) with those from Scopus and WoS. All the coefficients in Fig. 5 are significant at the 0.01 level (two-tailed).

5.4. Citations and recursive indicators

Finally, the resulting directed graph of citations between countries had 243 nodes (countries) and 2472 edges (citations between them). There were no parallel edges in the graph. Instead, a weight was assigned to each edge denoting from how many parallel edges the edge was created. The sum of weights in the whole graph was about 1.5 million.

In Table 5, we can see the top 80 countries ordered descendingly by their in-degree in the country citation graph. In the first case (“In-degree”) the edge weights are all set to one, in the second case (“Citations”) they are left as they are. Both rankings place USA, Germany, and the United Kingdom at the top with approximately 48%, 8%, and 6% of all citations, respectively. The rank four in in-degree is tied by Canada and France with the same number of citing countries (74) but, in total, France is cited more often by foreign countries and is positioned ahead of Canada in Citations. A similar behaviour may be observed with several other countries. The country rankings in Table 6 were obtained by applying recursive techniques, but despite their much higher computational costs they do not seem to provide any striking new information, though. We found the five rankings in Tables 5 and 6 to be very highly positively correlated with each other with Spearman’s ρ between 0.97 and 1 (all significant at the 0.01 level two-tailed).

6. Conclusions and future work

We have presented a thorough study of CiteSeer data with focus on countries and territories with which authors of publications indexed by CiteSeer are affiliated. The main contributions of the study are the following:

- We show from which parts of the Web CiteSeer and CiteSeer^X gathered its documents in terms of shares of top-level Internet domains in article sources.
- We analyze country shares in CiteSeer publications. (Unfortunately, CiteSeer^X does not have the information needed for this kind of analysis.)
- We compare the CiteSeer ranking to country shares of computer science publications from the Web of Science and Scopus to test the reliability of the productivity ranking.
- We submit CiteSeer data to a citation analysis and determine the most influential countries in terms of in-degree, citations, HITS, PageRank, and weighted PageRank.

Based on our analysis, we have obtained the following key results:

- Both CiteSeers collected computer science papers mainly from North American domains, followed by the domains of developed European and Asian countries. The top domains are *.com*, *.de*, *.edu*, *.fr*, *.org*, and *.uk*.
- United States is by far the greatest producer of computer science research papers although West European countries are, relatively at least, very competitive. Germany, France, and the United Kingdom can be named as a few examples.
- CiteSeer rankings of countries by publications and citations are very similar to those generated by the Web of Science or Scopus with a notable difference that CiteSeer apparently underestimates the potential of mainland China, South Korea, and Taiwan.
- Recursive techniques such as PageRank do not provide much new information on the influence of countries compared to simple citation counts. More or less, they confirm that popularity and prestige are close terms in the rankings of countries.

The study presented in this paper is the first of its kind that seeks to determine the most influential countries in computer science by analyzing the free CiteSeer digital library data. It complements the paper by Fiala (2011), which is concerned with individual authors in CiteSeer. From the papers listed in the literature review, the research conducted by Wainer et al. (2009) is closest to ours in that it evaluates the scientific output in computer science of several (thirteen) countries. However, it just examines publications from the Web of Science and Scopus from 2001 to 2005 and is not at all concerned with citations. Even less countries (six) are explored by Guan and Ma (2004) for the period of 1993–2002. Both studies, in accordance with our results, document a clear superiority of the USA over the rest of the world in computer science research. Unfortunately, there seems to be no previous complex computer science study for countries with which we could compare our findings.

Although CiteSeer data are far from complete and precise (in our experience, some 10% of the existing information might be erroneous), we may conclude that CiteSeer is a free digital library of valuable data and may be successfully used in bibliometric studies, possibly along with other well-known bibliographic databases, as we have shown in this paper. Let us underline in this place that the results we present depend solely on the content and quality of CiteSeer data. If other

regions of the Web had been crawled, if Asian paper repositories had been preferred by authors (see Section 5.1), or if the information extraction from papers done by CiteSeer had been more precise and complete, the outcomes of our analysis could have been different. Let us hope in this respect that CiteSeer^x will acquire data in a more standardized and transparent way and that it will enrich its metadata with the information on addresses and affiliations as well. Our future work on CiteSeer will concentrate on the citation analysis of institutions and on other reliability measures of CiteSeer data as well as on exploring further differences between the data in CiteSeer and CiteSeer^x.

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