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Fifty years of Information Sciences: A bibliometric overview

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ABSTRACT

Information Sciences is a leading international journal in computer science launched in 1968, so becoming fifty years old in 2018. In order to celebrate its anniversary, this study presents a bibliometric overview of the leading publication and citation trends occurring in the journal. The aim of the work is to identify the most relevant authors, institutions, countries, and analyze their evolution through time. The paper uses the Web of Science Core Collection in order to search for the bibliographic information. Our study also develops a graphical mapping of the bibliometric material by using the visualization of similarities (VOS) viewer. With this software, the work analyzes bibliographic coupling, citation and co-citation analysis, co-authorship, and co-occurrence of keywords. The results underline the significant growth of the journal through time and its international diversity having publications from countries all over the world.

1. Introduction

Information Sciences is a leading international journal in computer science focused on research connected to information, intelligent systems and knowledge engineering. John M. Richardson was the founding Editor-in-Chief. The current editor-in-chief took this position at the end of 2003 when Paul P. Wang, from Duke University, stepped down. In 1968, Information Sciences published only one issue and during the first years, it became a quarterly journal. In 1975, the journal increased to eight issues and in 1978, to nine issues divided in three volumes. In the nineties, the journal grew again publishing twenty-four issues per year and in 2012, it increased to thirty-six issues. Since 2016, the journal is publishing forty-eight issues every year, which proves the strong impact it is having in the scientific community with thousands of paper submissions from all over the world. In the 2016 Journal Citation Reports of the Web of Science, currently owned by Clarivate Analytics, the journal has an impact factor of 4.832, being in the 7th position out of 146 journals in the Web of Science Core Collection category of Computer Science, Information Systems. The journal is usually close to the top in most of the rankings in its field according to a wide range of measures including the five-year impact factor, the article influence score and the CiteScore.

Motivated by the journal's 50th anniversary, this paper develops a bibliometric analysis of the leading trends occurring therein. The aim is to identify the most significant aspects of the journal in terms of most cited papers, authors, institutions,

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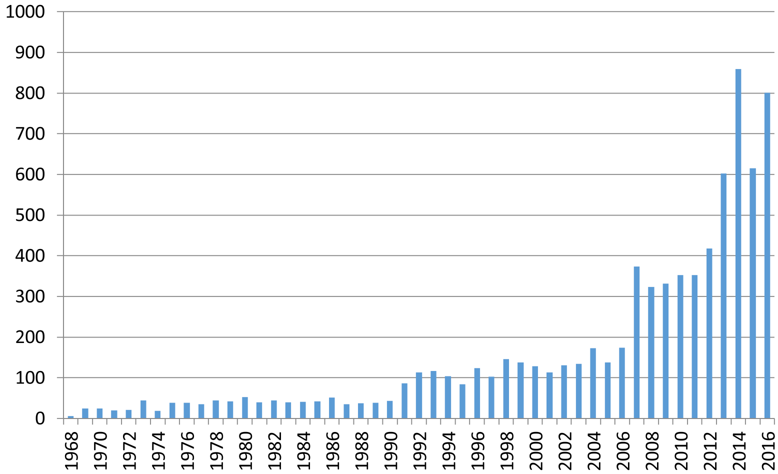

Fig. 1. Annual number of papers published in IS.

and countries. For doing so, the work analyzes all the documents published in the journal between 1968 and 2016 using the Web of Science Core Collection. The study also applies the Visualization of Similarities (VOS) viewer software [39] to map graphically the bibliographic material by employing a wide range of bibliometric methods including bibliographic coupling [22] and co-citation [35].

Observe that it is very common in the literature to develop some special activities when the journal celebrates a significant anniversary including editorials [2,34], reviews [40], and special issues [23]. Note that these anniversaries may also affect topics such as fuzzy set –based research [45], a significant field in the aims and scope of Information Sciences that celebrated the 50th anniversary in 2015. This event attracted a lot of attention with the publication of several special issues [12,20], representative papers [15,47] and some bibliometric overviews [28].

Many journals have presented a bibliometric analysis of the publications of the journal, especially through the celebration of their anniversary. For example, Heck and Bremser [19] study the first six decades of the Accounting Review. Schwert [33] presents a retrospective evaluation of the Journal of Financial Economics and Borokhovich et al. [6] of the Financial Management journal. Ramos–Rodríguez and Ruíz–Navarro [32] characterize the Strategic Management Journal between 1980 and 2000, and García–Merino et al. [17] the first twenty-five years of Technovation. Biemans et al. [3] present an historical overview of the first twenty years of the Journal of Product Innovation Management, and Weiss and Qiu [41] of the first seventy-five years of the Journal of Risk and Insurance. Merigó et al. [29] develop a bibliometric analysis of the Journal of Business Research and Cobo et al. [10] of Knowledge-Based Systems. Recently, some other authors provide a bibliometric overview of other journals including the International Journal of Intelligent Systems [26], the Journal of Business & Industrial Marketing [37], Computers & Industrial Engineering [8] and the European Journal of Operational Research [24].

This paper is organized as follows. Section 2 reviews the bibliometric methods used in this paper. Section 3 presents the results including the publication and citation structure, and the leading authors, institutions and countries publishing in the journal. Section 4 develops a graphical analysis of the bibliographic data of Information Sciences with VOS viewer software. Section 5 summarizes the main findings and concludes the paper.

2. Bibliometric methods

Bibliometrics is a research area of information and library sciences that analyzes bibliographic data, such as year of publication, authors, country of origin, among others, by using a quantitative approach [7,31]. The development of a bibliometric analysis is very useful in order to classify and provide a representative overview of a set of bibliographic documents. In the literature, many bibliometric studies analyze a wide range of issues including topics, journals [36], institutions [11] and countries [5]. There are also several bibliometric overviews close to the aims and scope of the journal Information Sciences including fuzzy research [28], intuitionistic fuzzy sets [44], fuzzy decision making [4], linguistic decision making [43], aggregation operators [42], the ordered weighted average [16], computational intelligence [38], data mining [25] and ant colony optimization [13].

There are many different bibliometric indicators to represent the respective information, such as the number of papers and citations [14,18]. This study considers several of them in order to provide different perspectives so each reader can understand the results according to their specific interests and priorities. The reason for doing so is that today there is no consensus regarding a single optimal method that can correctly evaluate a set of documents. Depending on the problem, a method may be better than another one. From a general point of view, the two main perspectives to evaluate research are productivity and influence [30]. Productivity is usually measured with the number of publications, while the influence by the number of citations. However, there are other indicators for doing so and many exceptional situations may arise. Some

Table 1
The 50 most cited papers in IS between 1968 and 2016.

R	TC	Title	Author/s	Year	C/Y
1	5550	Concept of a linguistic variable and its application to approximate reasoning. 1.	Zadeh, LA	1975	135,37
2	2357	Concept of a linguistic variable and its application to approximate reasoning. 2.	Zadeh, LA	1975	57,49
3	2352	Concept of a linguistic variable and its application to approximate reasoning. 3.	Zadeh, LA	1975	57,37
4	1149	Similarity relations and fuzzy orderings	Zadeh, LA	1971	25,53
5	919	GSA: A gravitational search algorithm	Rashedi, E; Nezamabadi-Pour, H; Saryazdi, S	2009	131,29
6	871	Rudiments of rough sets	Pawlak, Z; Skowron, A	2007	96,78
7	655	Fuzzy random-variables 1. Definitions and theorems	Kwakernaak, H	1978	17,24
8	606	Toward a generalized theory of uncertainty (GTU)- an outline	Zadeh, LA	2005	55,09
9	592	Rough set approach to incomplete information systems	Kryszkiewicz, M	1998	32,89
10	552	Rough sets: Some extensions	Pawlak, Z; Skowron, A	2007	61,33
11	550	A procedure for ordering fuzzy subsets of the unit interval	Yager, RR	1981	15,71
12	514	Networks of constraints-fundamental properties and applications to picture processing	Montanar, U	1974	12,24
13	491	A review of fuzzy set aggregation connectives	Dubois, D; Prade, H	1985	15,84
14	481	Centroid of a type-2 fuzzy set	Karnik, NN; Mendel, JM	2001	32,07
15	479	Rough sets and Boolean reasoning	Pawlak, Z; Skowron, A	2007	53,22
16	472	Ranking fuzzy numbers in the setting of possibility theory	Dubois, D; Prade, H	1983	14,30
17	467	Is there a need for fuzzy logic?	Zadeh, LA	2008	58,38
18	463	Advanced nonparametric tests for multiple comparisons in the design of experiments in computational intelligence and data mining: Experimental analysis of power	Garcia, S; Fernandez, A; Luengo, J; et al.	2010	77,17
19	462	On the Dempster-Shafer framework and new combination rules	Yager, RR	1987	15,93
20	462	An introductory survey of fuzzy control	Sugeno, M	1985	14,90
21	434	Constructive and algebraic methods of the theory of rough sets	Yao, YY	1998	24,11
22	424	Relational interpretations of neighborhood operators and rough set approximation operators	Yao, YY	1998	23,56
23	376	A study of particle swarm optimization particle trajectories	van den Bergh, F; Engelbrecht, AP	2006	37,60
24	364	On observability of discrete-event systems	Lin, F; Wonham, WM	1988	13,00
25	363	A method based on linguistic aggregation operators for group decision making with linguistic preference relations	Xu, ZS	2004	30,25
26	353	Soft sets and soft groups	Aktas, H; Cagman, N	2007	39,22
27	351	Reduction and axiomatization of covering generalized rough sets	Zhu, W; Wang, FY	2003	27,00
28	351	Rules in complete information systems	Kryszkiewicz, M	1999	20,65
29	332	Generalized fuzzy rough sets	Wu, WZ; Mi, JS; Zhang, WX	2003	25,54
30	320	Fuzzy least-squares	Diamond, P	1988	11,43
31	309	Intuitionistic preference relations and their application in group decision making	Xu, ZS	2007	34,33
32	304	Uncertain linguistic aggregation operators based approach to multiple attribute group decision making under uncertain linguistic environment	Xu, ZS	2004	25,33
33	298	A sequential selection process in group decision-making with a linguistic assessment approach	Herrera, F; Herrera-Viedma, E; Verdegay, JL	1995	14,19
34	294	Large scale evolutionary optimization using cooperative coevolution	Yang, Z; Tanga, K; Yao, X	2008	36,75
35	293	Distance and similarity measures for hesitant fuzzy sets	Xu, ZS; Xia, MM	2011	58,60
36	291	A modified Artificial Bee Colony algorithm for real-parameter optimization	Akay, B; Karaboga, D	2012	72,75
37	288	Rough sets and intelligent data analysis	Pawlak, Z	2002	20,57
38	286	Advances in type-2 fuzzy sets and systems	Mendel, JM	2007	31,78
39	286	Generalizing database relational algebra for the treatment of incomplete or uncertain-information and vague queries	Prade, H; Testemale, C	1984	8,94
40	280	Fuzzy random-variables 2. Algorithms and examples for the discrete case	Kwakernaak, H	1979	7,57
41	275	Teaching-Learning-Based Optimization: An optimization method for continuous non-linear large scale problems	Rao, RV; Savsani, VJ; Vakharia, DP	2012	68,75
42	262	Constructive and axiomatic approaches of fuzzy approximation operators	Wu, WZ; Zhang, WX	2004	21,83
43	251	The induced generalized OWA operator	Merigó, JM; Gil-Lafuente, AM	2009	35,86
44	251	Extensions and intentions in the rough set theory	Bonikowski, Z; Bryniarski, E; Wybraniec-Skardowska, U	1998	13,94
45	250	Fuzzy group decision-making for facility location selection	Kahraman, C; Ruan, D; Dogan, I	2003	19,23
46	247	Quantitative fuzzy semantics	Zadeh, LA	1971	5,49
47	239	Fuzzy entropy and conditioning	Kosko, B	1986	7,97
48	238	Neighborhood rough set based heterogeneous feature subset selection	Hu, Q; Yu, D; Liu, J; et al.	2008	29,75
49	234	Approaches to knowledge reduction based on variable precision rough set model	Mi, JS, Wu, WZ; Zhang, WX	2004	19,50
50	232	Topological approaches to covering rough sets	Zhu, W	2007	25,78

Abbreviations: R = Rank; TC = Total citations; C/Y = Citations per year.

Table 2
Documents most cited by IS publications.

R	Year	Cited reference (only first author)	Type	Citations	TLS
1	1965	Zadeh LA, Inform Control, V8, P338	A	544	436
2	1982	Pawlak Z, Int J Comput Inf Sci, V11, P341	A	263	252
3	1975	Zadeh LA, Inform Sciences, V8, P199	A	246	230
4	2005	Zadeh LA, Inform Sciences, V172, P1	A	202	174
5	1991	Pawlak Z., Rough Sets	B	184	165
6	1989	Goldberg DE, Genetic Algorithms	B	162	92
7	1995	Kennedy J, IEEE Int Conf Neural Networks Proc, Vols 1–6, P1942	C	148	121
8	2008	Zadeh LA, Inform Sciences, V178, P2751	A	129	119
9	2007	Pawlak Z, Inform Sciences, V177, P3	A	128	125
10	1975	Zadeh LA, Inform Sciences, V9, P43	A	127	123
11	2013	Pedrycz W, Granular Computing	B	123	102
12	1978	Zadeh LA, Fuzzy Sets Syst, V1, P3	A	123	90
13	1985	Takagi T, IEEE T Syst Man Cyb, V15, P116	A	117	45
14	1995	Klir GJ, Fuzzy Sets and Fuzzy Logic	B	116	98
15	1986	Atanassov KT, Fuzzy Set Syst, V20, P87	A	115	110
16	1975	Zadeh LA, Inform Sciences, V8, P301	A	114	114
17	1976	Shafer G, Mathematical Theory of Evidence	B	111	87
18	2000	Klement EP, Triangular Norms	B	107	85
19	1971	Rosenfeld A, J Math Anal Appl, V35, P512	A	107	78
20	2007	Pawlak Z, Inform Sciences, V177, P28	A	105	105
21	1988	Yager RR, IEEE T Syst Man Cyb, V18, P183	A	104	79
22	1990	Dubois D, Int J Gen Syst, V17, P191	A	96	95
23	2006	Demsar J, J Mach Learn Res, V7, P1	A	95	70
24	1998	Yao YY, Inform Sciences, V109, P21	A	94	94
25	1993	Quinlan JR, C4 5 Programs for Machine Learning	B	91	53
26	1997	Storn R, J Global Optim, V11, P341	A	88	70
27	2007	Pawlak Z, Inform Sciences, V177, P41	A	87	85
28	2002	Deb K, IEEE T Evolut Comput, V6, P182	A	84	39
29	1973	Zadeh LA, IEEE T Syst Man Cyb, Vsmc3, P28	A	84	68
30	1981	Bezdek JC, Pattern Recognition	B	83	48
31	1980	Dubois D, Fuzzy Sets and Systems	B	80	73
32	1998	Yao YY, Inform Sciences, V111, P239	A	79	79
33	1971	Zadeh LA, Inform Sciences, V3, P177,	A	78	62
34	2001	Mendel JM, Uncertain Rule Based Fuzzy Logic Systems	B	77	70
35	1979	Garey M, Computers Intractability	B	76	18
36	1998	Vapnik VN, Statistical Learning Theory	B	73	39
37	2006	Liang JJ, IEEE T Evolut Comput, V10, P281	A	72	68
38	1975	Holland JH, Adaptation in Natural and Artificial Systems	B	72	58
39	1994	Fodor J, Fuzzy Preference Modeling	B	70	62
40	1980	Saaty TL, Analytic Hierarchy Process	B	70	46

Abbreviations: A = Article; B = Book; C = Conference proceedings; TLS = Total Link Strength.

authors [1] have tried to unify productivity and influence in the same indicator. A very popular measure is the *h*-index [21] that combines them by finding the threshold that connects the number of documents with the number of citations. That is, if a set of documents has an *h*-index of X, this set has X documents that have received X or more citations and at the same time there are not $X+1$ documents that have received $X+1$ citations or more.

The work also considers other bibliometric indicators including the cites per paper, the cites per year, citation thresholds, citing articles, and the evolution through time. For countries, the analysis uses the number of papers and citations per million inhabitants. At the university level, the work complements the data with the ranking of the universities in the Academic Ranking of World Universities (ARWU) and the Quacquarelli and Symonds (QS) University Ranking.

Additionally, the study also maps graphically the bibliographic material by using the VOS viewer software [39]. The VOS viewer collects the data and builds maps in terms of bibliographic coupling, citation, co-citation, co-authorship and co-occurrence of author keywords. Recall that bibliographic coupling counts the documents that cite the same third document [22]. This is useful to identify similar research profiles. Citation analysis identifies how the documents cite each other counting the number of times that A cites B and vice versa. Co-citation occurs when two documents receive a citation from the same third source [35]. Co-authorship counts the documents that are co-authored by more than one author, institution or country and shows how they are connected. Co-occurrence of author keywords identifies the most frequent keywords and those keywords that appear more frequently in the same documents. Finally, note that in the literature there is a wide range of software for mapping bibliographic data [9].

Our analysis uses the Web of Science Core Collection database that is currently owned by Clarivate Analytics. The initial search selects the option of "publication name" and introduces the keyword "Information Sciences". The search has taken place in September 2016 and later updated between January and May 2017. The analysis considers all the documents published in the journal between 1968 and 2016. Information Sciences has published 8015 documents during this period. This

Table 3
Annual citation structure of IS.

Year	TP	TC	≥ 200	≥ 100	≥ 50	≥ 20	≥ 10	≥ 5	≥ 1
1968	6	62	0	0	0	1	3	3	5
1969	24	373	0	1	1	5	6	10	17
1970	24	316	1	1	1	3	4	7	17
1971	20	1743	2	3	5	7	10	11	17
1972	21	124	0	0	0	0	6	11	17
1973	44	429	1	1	2	4	6	14	29
1974	19	640	1	1	1	3	5	8	15
1975	38	10,347	3	3	3	3	4	9	27
1976	38	253	0	0	0	3	11	12	26
1977	35	197	0	1	1	1	3	9	21
1978	44	894	1	1	1	4	10	14	29
1979	42	514	1	1	2	4	8	14	28
1980	52	368	0	1	3	3	8	12	36
1981	40	751	1	1	2	3	3	11	28
1982	44	650	1	2	4	5	11	20	30
1983	39	858	1	1	3	7	11	15	27
1984	41	701	1	1	2	7	16	21	34
1985	42	1615	2	3	6	12	17	24	36
1986	51	666	1	2	2	7	12	20	39
1987	35	760	1	1	2	5	8	18	29
1988	37	1121	2	3	4	6	11	17	28
1989	38	192	0	0	1	2	4	12	28
1990	43	285	0	0	1	3	10	16	36
1991	86	566	0	0	2	7	15	29	58
1992	113	851	0	1	1	16	25	39	80
1993	116	761	0	1	3	10	19	38	79
1994	104	539	0	0	1	4	18	33	74
1995	84	878	1	2	3	8	15	32	64
1996	123	906	0	1	5	9	21	40	95
1997	102	843	0	0	4	9	20	36	85
1998	146	3897	4	9	16	27	53	79	119
1999	137	2176	1	4	9	29	49	73	116
2000	128	2121	0	2	8	35	64	85	121
2001	113	2324	1	3	10	28	54	74	107
2002	131	2611	1	6	14	32	55	83	117
2003	134	2883	3	4	9	32	69	95	127
2004	173	4903	5	5	27	68	100	132	168
2005	138	4459	1	9	23	64	91	111	134
2006	174	4216	1	3	22	69	106	139	171
2007	373	13,571	8	22	63	183	267	321	368
2008	323	10,689	4	18	62	171	239	284	319
2009	331	9152	2	11	39	143	213	282	322
2010	353	9012	3	8	43	146	240	305	350
2011	353	8908	1	13	46	139	243	304	349
2012	418	8435	2	8	31	139	236	340	406
2013	602	8572	0	6	21	130	297	431	578
2014	859	8848	0	2	14	121	302	509	807
2015	615	4165	0	1	4	41	129	285	560
2016	801	1305	0	0	0	2	13	75	471
Total	7847	137,763	58	167	527	1760	3140	4562	6844
%	100,00%		0,74%	2,13%	6,72%	22,43%	40,02%	58,14%	87,22%

Abbreviations: TP and TC = Total papers and citations; ≥ 200, ≥ 100, ≥ 50, ≥ 20, ≥ 10, ≥ 5, ≥ 1 = Number of papers with equal or more than 200, 100, 50, 20, 10, 5 and 1 citations.

number reduces to 7847 if only articles, reviews, letters, and notes are considered. Up to January 2017, the journal has received 137,763 citations from other documents available in Web of Science database. This makes an average number of cites per paper of 17.56. The *h*-index is 119. That is, of the 7847 documents, 119 have received 119 citations or more.

3. Results

3.1. Publication and citation structure

The first issue of Information Sciences was published in 1968. The journal is growing significantly through time. This can be explained by the strong development of advanced information technology during the last decades that has stimulated a huge amount of research in Information Sciences. Fig. 1 presents the annual number of documents published in the journal. Note that the figure only considers articles, reviews, letters, and notes.

Table 4
Citing articles of IS: Authors, universities, countries and journals.

R	Author	TP	University	TP	Country	TP	Journal	TP
1	Pedrycz, W	299	Chinese U Sciences	980	China	17,794	Inform Sci	5233
2	Xu, ZS	248	Islamic Azad U	918	USA	6913	Fuzzy Set Syst	2174
3	Yager, RR	217	U Granada	687	Taiwan	4036	Exp Syst App	1528
4	Herrera, F	210	CNRS France	609	Spain	3257	App Soft Comp	1195
5	Davvaz, B	160	Harbin Institute of Tech	590	Iran	3242	J Intel Fuzzy Syst	1038
6	Li, YM	160	Indian Institute of Tech	566	India	3226	Neurocomputing	994
7	Chang, CC	154	Hauzhong U Science Tech	547	UK	2626	Knowl-Based Syst	812
8	Shi, P	148	Northeastern U China	533	Canada	2197	IEEE T Fuzzy Syst	801
9	Mesiar, R	141	City U Hong Kong	496	South Korea	2115	Math Prob Engin	719
10	Dubois, D	123	Tsinghua U	487	Turkey	1927	Soft Comp	661
11	Zhan, JM	120	Xidian U	465	Australia	1776	Int J Intel Syst	446
12	Huang, GH	117	Dalian U Technology	450	France	1646	Int J Approx Reason	430
13	Herrera-Viedma, E	116	Southeast U China	441	Italy	1570	Eur J Oper Res	410
14	Prade, H	115	Polish Academy of Sciences	437	Japan	1472	Int J Uncert Fuzz KBS	399
15	Chen, SM	111	King Abdulaziz U	409	Poland	1210	App Math Comp	356
16	Jun, YB	107	Zhejiang U	401	Germany	1205	Neural Comp App	348
17	Kahraman, C	105	U Electronic Sci Tech China	398	Malaysia	894	Comp Ind Engin	332
18	Bustince, H	104	Shanghai Jiao Tong U	397	Brazil	853	Pattern Recog	317
19	Chen, XH	104	Xi an Jiaotong U	390	Saudi Arabia	816	Eng App Artif Intel	311
20	Xu, JP	98	Hong Kong Polytechnic U	388	Singapore	690	Comp Math App	305
21	Tong, SC	97	U Alberta	387	Belgium	613	Int J Syst Sci	299
22	De Baets, B	88	Beihang U	378	Greece	603	Theoret Comput Sci	293
23	Merigó, JM	87	National Chiao Tung U	376	Czech Rep	536	Fundam Inform	281
24	Oh, SK	78	Sichuan U	372	Pakistan	511	Int J Comp Intel Syst	275
25	Hu, QH	77	Nanyang Technological U	363	Mexico	461	Int J Adv Manuf Tech	265
26	Pal, SK	77	U Tehran	355	Netherlands	447	App Math Model	264
27	Liang, JY	77	Central South U	350	Romania	359	PLOS One	254
28	Castillo, O	77	National Taiwan U Sci Tech	339	Egypt	348	Int J Prod Res	225
29	Mendel, JM	76	Amirkabir U Technology	337	Austria	311	Nonlinear Dynam	224
30	Tzeng, GH	73	Southwest Jiaotong U	327	Portugal	287	Multimedia Tools App	223

Abbreviations available in Tables 1 and 3.

During the first twenty years, the journal was publishing around forty papers per year. In the nineties, this number grew to one hundred and in the first decade of the millennium, to three hundred. In 2014, the journal reached a top of 859 documents and in 2016, the number was 801. Note that currently the journal has an acceptance rate around 20%.

Information Sciences has published many significant publications in the field of computer science. Table 1 presents the fifty most cited papers of the journal of all-time.

The three most cited papers represent the seminal contributions of Lotfi A. Zadeh to the development of linguistic research in fuzzy logic and computer science. Note that the first one is among the fifty most cited papers in computer science of all-time [48] and the other two among the two-hundred most cited. Apart from having, the four most cited papers of all-time in the journal, Zadeh has a total of seven papers in the Top 50. Zdzislaw Pawlak and Zeshui Xu have four papers in the list, and Andrzej Skowron and Henri Prade, three.

Another interesting issue is to consider those documents that receive most citations by papers published in the journal. In order to do so, our study uses the VOS viewer software and generates the co-citations of documents identifying those documents that are most cited in the journal. Table 2 presents the Top 40.

The document most cited in Information Sciences is the seminal paper of Lotfi A. Zadeh about "Fuzzy Sets" published in Information and Control in 1965. Note that this paper is the most cited paper of all-time in computer science [48] and among the fifty most cited of all-time in all sciences [28]. The second one is the seminal paper of Zdzislaw Pawlak on "Rough Sets" published in the International Journal of Computers & Information Sciences in 1982. The third and fourth papers in the list are also from Zadeh and published in Information Sciences in 1975 and 2005. These two documents appear in Table 2 in the first and eighth position, respectively. Zadeh also leads this list with nine documents. Pawlak has five documents in the Top 40.

Next, let us look into the citation structure of the journal. For doing so, the work analyzes the annual number of documents published in the journal and reports the number of citations they have achieved considering several citation thresholds. Table 3 presents the results.

The number of citations is growing through time especially thanks to the significant growth of the Web of Science that currently indexes more than fifteen thousand journals. About 2% of the papers have more than one hundred citations and 40% more than ten citations. 87% of the papers at least have received one citation in documents indexed in Web of Science.

In order to identify the origin of the citations of Information Sciences, let us analyze the citing articles in Web of Science. Note that this option is available in the database in the citation report generated when considering all the documents published in the journal. Table 4 presents the Top 30 authors, institutions, countries, and journals that cite papers published in Information Sciences.

Table 5
Most productive authors in IS.

R	Author Name	University	Country	TP	TC	H	C/P	≥ 200	≥ 100	≥ 50
1	Yager, RR	Iona Col	USA	48	2351	22	48,98	2	5	9
2	Herrera, F	U Granada	ESP	41	2467	21	60,17	2	8	15
3	Shi, P	U Adelaide	AUS	35	780	16	22,29	0	0	5
4	Mesiar, R	Slovak U Tech	SLK	35	581	14	16,60	0	0	1
5	Chang, CC	Feng Chia U	TWN	34	687	14	20,21	0	2	2
6	Pal, SK	Indian Stat Inst	IND	29	666	12	22,97	0	2	2
7	Castillo, O	Tijuana Inst Tech	MEX	28	1123	17	40,11	0	4	8
8	Inoue, K	Yamaguchi U	JAP	27	281	8	10,41	0	1	1
9	Davvaz, B	Yazd U	IRA	26	837	19	32,19	0	0	5
10	Bustince, H	Pub U Navarra	ESP	26	601	11	23,12	0	1	4
11	Pedrycz, W	U Alberta	CAN	26	457	11	17,58	0	1	2
12	Xu, ZS	Sichuan U	CHN	25	2487	15	99,48	4	10	13
13	Li, YM	Liaoning U Tech	CHN	25	519	13	20,76	0	0	2
14	Chen, SM	NTU Sci Tech	TWN	25	294	10	11,76	0	0	0
15	Kandel, A	U South Florida	USA	25	241	9	9,64	0	0	1
16	Melin, P	Tijuana Inst Tech	MEX	24	977	16	40,71	0	3	7
17	Mendel, JM	U South Calif	USA	22	1738	14	79,00	2	6	9
18	Jun, YB	Gyeongsang Nat U	SK	22	793	13	36,05	0	2	6
19	Yao, YY	U Regina	CAN	21	2488	18	118,48	2	8	13
20	De Baets, B	Ghent U	BEL	21	283	10	13,48	0	0	1
21	Ruan, D	Ghent U	BEL	20	1072	16	53,60	1	3	8
22	Hu, QH	Tianjin U	CHN	19	807	12	42,47	0	2	4
23	Suganthan, PN	Nanyang Tech U	SGP	19	754	12	39,68	0	2	6
24	Turksen, IB	U Toronto	CAN	19	374	11	19,68	0	0	1
25	Rosenfeld, A	U Maryland CP	USA	19	195	7	10,26	0	0	0
26	Takanami, I	Polytech U	JAP	19	170	8	8,95	0	0	0
27	Wang, W	Dalian U Tech	CHN	18	389	10	21,61	0	1	1
28	Herrera-Viedma E	U Granada	ESP	17	1140	13	67,06	1	4	8
29	Vasilakos, AV	Lulea U Tech	SWE	16	418	10	26,13	0	1	3
30	Jiao, LC	Xidian U	CHN	16	215	10	13,44	0	0	1
31	Domingo-Ferrer J	U Rovira i Virgili	ESP	16	200	9	12,50	0	0	0
32	Mordeson, JN	Creighton U	USA	16	165	7	10,31	0	0	0
33	Zadeh, LA	UC Berkeley	USA	15	11,149	8	743,27	5	5	6
34	Das, S	Indian Stat Inst	IND	15	385	9	25,67	0	0	4
35	Tong, SC	Liaoning U Tech	CHN	15	336	12	22,40	0	0	2
36	Chen, DG	North China Elec PU	CHN	14	560	10	40,00	0	1	4
37	Pan, JS	Nat Kaohsiung UAS	TWN	14	460	12	32,86	0	0	3
38	Cao, ZF	Shanghai JT U	CHN	14	347	9	24,79	0	1	1
39	Liao, XF	Southwest U	CHN	14	312	9	22,29	0	0	2
40	Shih, FY	New Jersey Ins Tech	USA	14	293	8	20,93	0	0	3
41	Jaoua, A	Qatar U	QAT	14	97	4	6,93	0	0	1
42	Zhu, W	Minnan Normal U	CHN	13	1313	12	101,00	1	6	6
43	Liang, JY	Shanxi U	CHN	13	625	10	48,08	0	1	5
44	Yin, YQ	East China U Tech	CHN	13	326	9	25,08	0	1	1
45	Hirota, K	Tokyo Inst Tech	JAP	13	319	7	24,54	0	1	2
46	Li, TR	Southwest JT U	CHN	13	316	7	24,31	0	0	3
47	Rozenberg, G	Leiden U	NET	13	197	5	15,15	0	1	2
48	Sessa, S	U Naples Fed II	ITA	13	196	7	15,08	0	0	1
49	Xiong, NX	Colorado Tech U	USA	13	129	8	9,92	0	0	0
50	Dubois, D	CNRS	FRA	12	1293	9	107,75	2	4	4

Abbreviations available in Tables 1 and 3 except: C/P = Cites per paper; H = *h*-index.

The first four authors from the list have more than two hundred documents citing Information Sciences. Note that this result depends on the productivity of the author and previous studies have shown that these four authors are extremely productive ([28]; 2017). The Chinese Academy of Sciences leads the table in terms of institutions and China is clearly the leading country. Note that during the last years, China is growing significantly in computer science and engineering and today is already more productive than the USA. Observe that more than half of the institutions in the Top 30 are from China. From the journal perspective, the self-citations of Information Sciences are the most significant ones. Note that this is quite common for most of the journals. The majority of journals in the list are from computer science and engineering.

3.2. Leading authors, institutions and countries

In this section, let us analyze those authors, institutions, and countries that have most publications in the journal. First, let us look into the 50 most productive authors; see Table 5. Note that in the case of a tie, the ranking is according to the number of citations.

Table 6
Temporal evolution of the most productive authors.

	1968–1977			1988–1997				2008–2016		
R	Author	TP	TC	Author	TP	TC		Author	TP	TC
1	Lainiotis, DG	9	83	Pal, SK	16	363	1	Herrera, F	37	1876
2	Tanaka, K	8	38	Kandel, A	15	85	2	Mesiar, R	32	497
3	Zadeh, LA	6	11,887	Mordeson, JN	13	128	3	Shi, P	31	608
4	Sage, AP	6	15	Yager, RR	10	242	4	Bustince, H	24	446
5	Sorenson, HW	5	89	Ray, S	9	24	5	Chen, SM	24	292
6	Batchelor, BG	5	11	Kuroki, N	8	281	6	Castillo, O	22	840
7	Schwartz, L	5	3	Malik, DS	8	100	7	Xu, ZS	21	1417
8	Fu, KS	4	44	Aoe, JI	8	18	8	Davvaz, B	21	543
9	Mizumoto, M	4	32	Chang, CC	7	13	9	Suganthan, PN	19	754
10	Toyoda, J	4	32	Kurz, L	7	11	10	Melin, P	18	693
11	Richardson, JM	4	3	Ajmal, N	6	82	11	Hu, QH	18	656
12	Bellman, R	3	215	Thomopoulos, SCA	6	75	12	Li, YM	18	377
13	Lindquist, A	3	32	Inoue, K	6	62	13	De Baets, B	18	221
14	Santos, ES	3	29	Pedrycz, W	6	27	14	Jiao, LC	16	215
15	Gupta, SC	3	28	Kim, JG	6	20	15	Yao, YY	15	1284
16	Baba, N	3	16	Kumar, V	6	19	16	Herrera-Viedma, E	15	660
17	Thomas, JB	3	10	Jaoua, A	6	11	17	Chang, CC	15	243
18	Casti, J	3	6	Lee, RCT	6	8	18	Yager, RR	15	222
19	Lo, JTH	3	4	Chung, CM	6	7	19	Wang, W	15	163
20	Sengupta, SS	3	2	Yang, WP	6	4	20	Vasilakos, AV	14	360
	1978–1987			**1998–2007**			21	Domingo-Ferrer, J	14	169
R	Author	TP	TC	Author	TP	TC	22	Mendel, JM	13	425
1	Yager, RR	14	1556	Jun, YB	14	380	23	Das, S	13	384
2	Takanami, I	14	108	Ruan, D	13	834	24	Li, TR	13	311
3	Inoue, K	14	108	Chen, GR	12	369	25	Xiong, NX	13	129
4	Rozenberg, G	8	176	Aoe, J	12	66	26	Liang, JY	12	562
5	Wood, D	7	46	Xu, Y	11	373	27	Chen, DG	12	401
6	Sharma, BD	7	20	Zhang, WX	9	1304	28	Cao, ZF	12	308
7	Bhattacharya, P	6	139	Yager, RR	9	344	29	Tong, SC	12	286
8	Fu, KS	6	87	Shih, FY	9	270	30	Liao, XF	12	207
9	Prade, H	5	1372	Pedrycz, W	9	269				
10	Taniguchi, H	5	33	Rosenfeld, A	9	141				
11	Chang, CC	5	29	Pal, SK	8	292				
12	Arora, PN	5	10	Turksen, IB	8	227				
13	Dial, G	5	0	Nguyen, HT	8	78				
14	Mukherjee, NP	4	131	Sadoun, B	8	71				
15	Oommen, BJ	4	66	Mendel, JM	7	1299				
16	Saitta, L	4	64	Yao, YY	6	1204				
17	Takatsu, S	4	37	Chang, CC	7	412				
18	Taneja, IJ	4	26	Hong, DH	7	297				
19	Yau, SS	4	12	Taniar, D	7	92				
20	Srihari, SN	4	11	Fuketa, M	7	52				

Abbreviations are available in the previous tables. Note that each five-year period indicates the number of papers and citations in that period.

Ronald R. Yager is the most productive author followed by Francisco Herrera. Note that both of them are among the most cited authors although Lotfi A. Zadeh is clearly leading the ranking of most cited authors with more than ten thousand citations. The nationality of the authors is very diverse although Chinese authors have the highest presence. However, it is worth mentioning that their influence is growing through time so this leading position may increase in the future. In order to see the most productive authors through time, Table 6 shows the leading authors in ten-year periods.

During the first years, the leading authors were from the USA. However, through time, their influence is decreasing in favor of emerging countries, particularly, China.

Next, let us analyze the most productive institutions. Observe that the institutions represent the affiliation of the authors when they published their papers in Information Sciences. Therefore, authors that have changed affiliation may have publications for different institutions.

The Chinese Academy of Sciences is the most productive institution followed by the University of Granada and the City University of Hong Kong. China leads the list with eighteen institutions, followed by Taiwan with eight, Spain with six and the USA with four.

Another interesting issue is to see the results through time. For doing so, Table 8 presents the most productive institutions in ten-year periods starting from 1968.

Table 7
The most productive and influential institutions in IS.

R	Institution	Country	TP	TC	H	C/P	≥250	≥100	≥50	ARWU	QS
1	Chinese Academy Sciences	CHN	146	2923	26	20,02	1	6	12	–	–
2	U Granada	ESP	112	3661	31	32,69	2	9	22	201–300	501–550
3	City U Hong Kong	CHN	101	1991	24	19,71	0	3	10	201–300	55
4	Xidian U	CHN	81	953	17	11,77	0	0	2	–	174
5	Harbin Institute of Technology	CHN	80	1906	26	23,83	0	2	11	151–200	278
6	National Chiao Tung U	TWN	79	1098	18	13,90	0	0	7	401–500	–
7	Huazhong U Science Technology	CHN	76	1113	19	14,64	0	2	4	201–300	131
8	Shanghai Jiao Tong U	CHN	70	1592	21	22,74	0	4	9	101–150	61
9	Ghent U	BEL	70	1517	22	21,67	0	1	9	62	24
10	Tsinghua U	CHN	68	1846	21	27,15	1	4	11	58	441–450
11	Zhejiang U	CHN	67	774	16	11,55	0	0	3	101–150	111
12	Nanyang Technological U	SGP	63	1469	22	23,32	0	2	11	101–150	–
13	Hong Kong Polytechnic U	CHN	63	1035	18	16,43	0	2	4	301–400	110
14	National Taiwan U Science Tech	TWN	63	726	16	11,52	0	0	1	–	243
15	Northeastern U China	CHN	60	908	15	15,13	0	1	3	–	46
16	CNRS	FRA	59	1129	14	19,14	1	2	4	–	–
17	Polish Academy of Sciences	POL	57	1090	17	19,12	0	3	7	–	–
18	KAIST	S.K	56	518	13	9,25	0	0	2	201–300	13
19	U Maryland College Park	USA	55	461	11	8,38	0	0	1	52	–
20	Southwest Jiaotong U	CHN	54	1332	23	24,67	0	1	8	–	481–490
21	Dalian U Technology	CHN	54	1266	20	23,44	0	3	6	–	131
22	National Tsing Hua U	TWN	52	528	12	10,15	0	0	2	301–400	151
23	U Oviedo	ESP	50	561	14	11,22	0	0	3	–	–
24	Xi an Jiaotong U	CHN	49	2392	25	48,82	2	6	13	–	318
25	U Delhi	IND	49	343	10	7,00	0	0	2	–	501–550
26	Iona College	USA	48	2294	22	47,79	2	5	9	–	–
27	U Electronic Science Tech China	CHN	47	1091	19	23,21	0	3	4	301–400	112
28	Yonsei U	S.K	46	672	14	14,61	0	0	3	201–300	136
29	Wuhan U	CHN	45	616	14	13,69	0	0	2	301–400	–
30	U Southern California	USA	44	2234	16	50,77	2	8	12	49	–
31	Shaanxi Normal U	CHN	43	776	14	18,05	0	2	2	–	–
32	Slovak U Technology Bratislava	SLK	43	625	14	14,53	0	0	1	–	–
33	Amirkabir U Technology	IRA	42	557	15	13,26	0	0	0	401–500	501–550
34	Feng Chia U	TWN	41	939	17	22,90	0	2	4	–	297
35	Korea U	S.K	40	370	11	9,25	0	0	1	151–200	–
36	Nanjing U Science Technology	CHN	39	731	15	18,74	0	1	3	401–500	–
37	Polytechnic U Madrid	ESP	39	512	11	13,13	0	0	2	–	275
38	National Sun Yat Sen U	TWN	39	375	9	9,62	0	0	1	151–200	98
39	Universidad de Jaen	ESP	38	2161	20	56,87	1	6	15	–	–
40	National Chung Cheng U	TWN	38	762	14	20,05	0	2	3	–	551–600
41	Sichuan U	CHN	38	655	16	17,24	0	0	3	201–300	551–600
42	Chinese U Hong Kong	CHN	37	787	14	21,27	0	1	5	201–300	–
43	Islamic Azad U	IRA	37	734	16	19,84	0	1	3	–	44
44	U Waterloo	CAN	36	426	11	11,83	0	0	2	201–300	–
45	U Public Navarra	ESP	35	686	14	19,60	0	1	4	–	–
46	National Cheng Kung U	TWN	35	566	13	16,17	0	0	2	401–500	239
47	National Chung Hsing U	TWN	35	333	11	9,51	0	0	1	–	241
48	Purdue U	USA	35	296	8	8,46	0	0	1	63	91
49	Complutense U Madrid	ESP	35	273	10	7,80	0	0	0	301–400	94
50	U Alberta	CAN	34	616	15	18,12	0	1	3	101–150	152

Abbreviations are in Tables 1 and 3 except: ARWU and QS = Ranking in the general ARWU and QS university rankings.

Initially, the universities of the USA were leading the list. However, through time other institutions are becoming more relevant, especially from China that during the last decade, have more than half of the twenty most productive universities.

In order to provide a general picture of the results of Tables 5–8, let us consider the country affiliation of the institutions where the authors are publishing their research in Information Sciences. Table 9 presents the fifty most productive countries in the journal.

China is already the most productive and influential country in the journal although still very close to the USA. However, their results are not so significant per million inhabitants. Under this perspective, Taiwan and Spain obtain the most remarkable results being in the third and fourth position, respectively, in absolute terms. Information Sciences, as many other computer science and engineering journals, shows a strong globalization with countries from all over the world publishing in the journal.

Next, let us analyze these results through time. In order to do so, Table 10 presents the number of papers published annually by the Top 40 countries. Note that the table focuses on the last nineteen years providing a total number for each of the first three decades.

Table 8
Temporal evolution of the most productive institutions.

	1968–1977			1988–1997				2008–2016		
R	University	TP	TC	University	TP	TC		University	TP	TC
1	Osaka University	8	28	University of Maryland College Park	20	104	1	University of Granada	92	2686
2	University of Maryland College Park	7	25	Creighton University	19	215	2	City University of Hong Kong	82	1456
3	SUNY Buffalo	6	73	University of Delhi	16	107	3	Xidian University	75	834
4	University of California San Diego	6	53	National Tsing Hua University	15	39	4	Huazhong University of Science Technology	72	1072
5	Southern Methodist University	6	9	Indian Institute of Technology IIT Kharagpur	14	70	5	Zhejiang University	64	747
6	University of California Berkeley	5	10,264	University of South Florida	13	66	6	Shanghai Jiao Tong University	61	1335
7	Technion Israel Institute of Technology	5	9	Florida State University	13	44	7	Hong Kong Polytechnic University	58	854
8	SUNY Maritime College	4	58	University of Florida	12	78	8	Northeastern University China	56	798
9	Youngstown State University	4	52	National Chiao Tung University	12	73	9	Nanyang Technological University	54	1348
10	Tokushima University	4	30	Iona College	10	241	10	Tsinghua University	53	831
11	Princeton University	4	11	Duke University	10	123	11	Ghent University	52	774
12	McMaster University	4	8	University of Minnesota Twin Cities	10	26	12	Dalian University of Technology	50	1007
13	University of Southampton	4	7	Polytechnic Institute New York	10	16	13	National Taiwan Univ Science Technology	47	592
14	Royal Institute of Technology	2	231	University of Southern California	9	52	14	Univ Electronic Science Technology of China	45	1065
15	University of Southern California	2	214	Joetsu University of Education	8	281	15	Wuhan University	44	610
16	University of Texas Austin	3	64	Louisiana State University	8	141	16	Southwest Jiaotong University	42	827
17	Washington State University	2	40	Penn State University	8	75	17	Slovak University of Technology Bratislava	40	539
18	University of California Los Angeles	2	31	University of North Carolina	8	47	18	Amirkabir University of Technology	40	522
19	University of Maryland Baltimore	3	9	Tokushima University	8	18	19	Sichuan University	38	655
20	Purdue University	3	8	University of Queensland	8	12	20	Nanjing University of Science Technology	34	533
	1978–1987			**1998–2007**			21	Islamic Azad University	34	528
R	University	TP	TC	University	TP	TC	22	National Chiao Tung University	33	684
1	University of Delhi	24	107	National Chiao Tung University	29	329	23	Feng Chia University	33	675
2	University of Maryland College Park	17	146	Xi An Jiaotong University	22	1815	24	Korea University	33	201
3	Yamaguchi University	16	123	Korea Advanced Inst Sci Tech	22	210	25	Universidad de Jaen	32	1730
4	Iona College	12	1463	City University of Hong Kong	19	535	26	Universidad Publica de Navarra	32	523
5	Purdue University	9	127	Ghent University	18	743	27	Polytechnic University of Madrid	32	389
6	University of Antwerp	8	172	University of Alberta	17	387	28	King Abdulaziz University	32	379
7	Univ Federal de Santa Catarina	8	26	Yonsei University	16	382	29	University of Oviedo	32	278
8	SUNY Buffalo	8	14	National Sun Yat Sen University	16	196	30	Tianjin University	32	231
9	Tokyo Institute of Technology	7	493	King Fahd University of Petroleum Minerals	16	142				
10	Northwestern University	7	15	National Chung Cheng University	15	537				
11	Florida State University	6	109	Gyeongsang National University	15	390				
12	Indian Institute of Technology Kharagpur	6	104	Tokushima University	15	80				
13	Indian Institute of Science Bangalore	6	76	Tsinghua University	14	1011				
14	University of Waterloo	6	45	University of Granada	14	561				
15	Kyoto University	6	21	University of Houston	14	345				
16	Universite Toulouse III Paul Sabatier	5	1364	University of Oviedo	14	266				
17	U Fed Toulouse Midi Pyrenees Comue	5	1364	Tamkang University	14	177				
18	Universite de Toulouse	5	1364	New Jersey Institute of Technology	13	320				
19	University of Turin	4	64	University of Salerno	13	195				
20	University of Illinois Chicago	4	47	Middle East Technical University	13	185				

Abbreviations are available in the previous tables.

Table 9
The most productive and influential countries in IS.

R	Country	TP	TC	H	C/P	≥250	≥100	≥50	P/Po	C/Po
1	China	2075	37,985	79	18,31	8	56	170	1,51	27,70
2	USA	1547	32,368	61	20,92	11	27	80	4,81	100,70
3	Taiwan	700	10,594	49	15,13	0	5	44	29,80	450,96
4	Spain	573	9642	46	16,83	3	13	43	12,34	207,72
5	South Korea	418	5401	37	12,92	0	6	21	8,26	106,70
6	UK	380	6753	42	17,77	1	9	34	5,83	103,67
7	India	346	4828	35	13,95	1	5	19	0,26	3,68
8	Japan	342	4727	34	13,82	1	6	18	2,69	37,23
9	Canada	329	7005	37	21,29	3	12	29	9,18	195,39
10	Australia	310	3545	29	11,44	0	2	11	13,04	149,07
11	Italy	272	3415	27	12,56	1	1	7	4,47	56,17
12	Iran	197	4352	31	22,09	1	2	16	2,49	55,01
13	France	196	3975	26	20,28	4	8	13	2,93	59,50
14	Turkey	189	5255	38	27,80	3	9	26	2,40	66,80
15	Poland	173	6171	32	35,67	7	10	22	4,55	162,40
16	Brazil	162	2075	24	12,81	0	3	8	0,78	9,98
17	Germany	137	1614	22	11,78	0	1	5	1,68	19,82
18	Belgium	123	2715	30	22,07	1	4	16	10,90	240,57
19	Singapore	118	2192	27	18,58	0	2	13	21,32	396,03
20	Czech Republic	108	1090	18	10,09	0	0	2	10,24	103,31
21	Greece	94	1414	22	15,04	0	1	8	8,68	130,64
22	Saudi Arabia	87	934	18	10,74	0	0	4	2,76	29,61
23	Slovakia	73	819	16	11,22	0	0	1	13,46	150,99
24	Mexico	71	1753	24	24,69	0	4	11	0,56	13,80
25	Netherlands	70	1769	16	25,27	2	3	6	4,13	104,45
26	Malaysia	54	720	15	13,33	0	0	2	1,78	23,74
27	Finland	47	752	15	16,00	0	0	5	8,57	137,18
28	Israel	46	479	12	10,41	0	1	1	5,49	57,16
29	Egypt	41	378	11	9,22	0	0	1	0,45	4,13
30	Romania	39	691	14	17,72	0	2	3	1,97	34,84
31	Austria	39	597	13	15,31	0	1	3	4,53	69,33
32	Pakistan	37	559	14	15,11	0	1	3	0,20	2,96
33	Russia	35	227	8	6,49	0	0	1	0,24	1,58
34	Chile	32	543	11	16,97	0	0	5	1,78	30,25
35	Serbia	31	470	13	15,16	0	0	1	4,37	66,21
36	Tunisia	30	188	7	6,27	0	0	1	2,70	16,93
37	New Zealand	27	981	13	36,33	0	3	4	5,88	213,46
38	Portugal	26	297	10	11,42	0	0	0	2,51	28,70
39	Hungary	24	559	10	23,29	0	2	3	2,44	56,78
40	Sweden	24	450	9	18,75	0	1	2	2,45	45,92
41	Norway	24	447	10	18,63	0	1	1	4,62	86,03
42	Slovenia	20	272	7	13,60	0	0	1	9,69	131,80
43	Kuwait	19	271	8	14,26	0	0	2	4,88	69,63
44	South Africa	18	559	7	31,06	1	1	2	0,33	10,17
45	Ireland	18	139	7	7,72	0	0	0	3,88	29,95
46	Jordan	18	128	8	7,11	0	0	0	2,37	16,85
47	Qatar	16	160	7	10,00	0	0	1	7,16	71,58
48	U Arab Emirates	14	121	6	8,64	0	0	1	1,53	13,21
49	Vietnam	14	112	6	8,00	0	0	0	0,15	1,22
50	Argentina	14	65	6	4,64	0	0	0	0,32	1,50

Abbreviations available in previous tables except: P/Po and C/Po = Papers and cites per million inhabitants.

During the first three decades, China published less than thirty papers. This number started to grow significantly in 2007 and today China participates in almost half of the papers of Information Sciences. On the other side, the USA was the leader during the first thirty years but today it only participates in one tenth of the publications. Most of the countries are growing their numbers due to the growth of the journal in the annual number of papers.

Finally, let us summarize all the publications of the journal from a supranational perspective. For doing so, Table 11 presents the results.

East Asia is currently the most productive region, which indicates the strong impact the journal is having in these countries. North America and Western Europe obtain very similar results although the results of the USA are a bit better. It is worth noting the globalized perspective the journal has with publications from all over the world. Even Africa has published significantly in the journal although their numbers are still very low when comparing them with the rest of the regions.

Table 10
Temporal evolution of the country publications.

R	Country	D1	D2	D3	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	Total
1	China	0	8	21	5	8	13	7	10	20	31	33	21	91	111	94	107	116	153	206	357	265	398	2075
2	USA	112	161	387	54	44	46	43	37	54	36	23	30	61	33	33	44	38	30	55	81	56	89	1547
3	Taiwan	0	11	61	17	25	11	5	13	14	17	20	25	56	45	41	37	46	43	66	70	45	32	700
4	Spain	0	2	21	6	6	3	11	2	6	9	1	7	19	14	30	44	29	51	88	86	57	81	573
5	South Korea	0	2	21	5	6	8	5	12	10	12	11	21	31	24	23	24	20	29	30	51	29	44	418
6	UK	5	11	8	3	8	5	5	5	14	10	14	8	13	12	15	14	21	20	32	49	54	54	380
7	India	2	58	82	8	5	4	5	2	2	9	7	8	12	8	9	8	12	20	12	23	30	20	346
8	Japan	18	52	74	19	8	10	6	18	5	16	8	8	12	6	10	4	8	14	12	14	3	17	342
9	Canada	12	25	39	11	4	5	7	3	4	6	2	11	15	12	12	12	10	25	30	39	17	28	329
10	Australia	4	13	23	3	7	4	0	3	3	10	0	5	20	7	12	10	15	14	25	35	44	53	310
11	Italy	7	12	25	4	6	4	7	2	2	6	3	12	9	6	13	11	14	15	19	34	19	42	272
12	Iran	0	1	3	0	0	0	0	1	0	1	2	4	10	18	12	21	7	11	29	36	22	19	197
13	France	3	14	24	1	5	4	4	4	2	4	5	2	4	6	5	10	16	8	18	18	16	23	196
14	Turkey	0	0	3	3	3	4	2	4	1	11	4	15	22	18	13	14	8	14	13	19	12	6	189
15	Poland	0	5	12	8	4	1	2	5	1	1	3	8	8	3	9	3	4	15	16	27	13	25	173
16	Brazil	0	10	8	1	0	0	2	2	1	2	0	2	6	2	8	7	19	12	14	17	15	34	162
17	Germany	1	28	17	2	9	3	9	3	1	4	2	3	0	1	5	7	0	7	7	10	8	10	137
18	Belgium	3	11	4	3	2	3	3	6	5	2	2	2	8	3	5	12	10	6	9	9	6	9	123
19	Singapore	0	0	6	1	2	1	1	5	0	1	3	5	2	6	2	7	7	10	4	16	14	25	118
20	Czech Republic	0	0	1	0	0	2	0	1	0	1	1	0	3	1	10	10	10	10	11	21	13	13	108
21	Greece	0	3	11	0	0	2	1	2	4	1	4	6	11	6	2	9	3	2	0	8	13	6	94
22	Saudi Arabia	0	0	3	0	0	1	2	6	3	2	1	3	2	0	0	1	3	5	4	18	13	20	87
23	Slovakia	0	0	0	0	0	0	0	0	0	2	0	1	2	2	8	9	5	6	7	11	15	5	73
24	Mexico	0	1	0	0	0	0	0	2	0	2	1	0	4	1	5	1	6	10	3	13	11	11	71
25	Netherlands	1	12	6	1	1	4	2	2	3	2	5	2	3	2	1	1	2	0	6	5	4	5	70
26	Malaysia	0	0	0	0	0	1	0	0	2	3	1	0	2	1	0	2	4	2	4	14	13	5	54
27	Finland	1	6	2	1	2	0	4	0	0	1	1	0	3	2	1	1	3	2	4	3	5	5	47
28	Israel	6	5	9	1	0	0	1	0	0	0	1	1	2	0	2	3	1	3	2	5	3	1	46
29	Egypt	0	0	9	2	0	1	1	0	0	5	2	3	3	2	0	3	4	1	3	1	0	1	41
30	Romania	1	1	1	0	0	1	0	0	1	0	0	0	2	4	4	3	1	2	7	6	1	4	39
31	Austria	0	2	1	0	0	0	0	3	0	0	0	1	1	1	6	3	3	2	6	4	2	4	39
32	Pakistan	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	5	3	5	6	8	8	37
33	Russia	1	6	13	0	0	1	0	2	0	0	1	0	0	0	1	0	1	1	0	0	3	5	35
34	Chile	0	0	0	0	0	0	0	1	0	0	0	0	4	0	2	1	6	1	1	6	6	4	32
35	Serbia	0	0	0	0	0	0	0	0	0	0	0	0	2	3	2	4	5	3	2	6	2	2	31
36	Tunisia	0	0	8	3	2	1	0	2	0	3	0	0	1	0	0	0	2	1	1	3	1	2	30
37	New Zealand	0	0	1	1	0	2	0	1	3	0	0	1	5	1	0	2	1	0	3	2	2	2	27
38	Portugal	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	2	1	2	2	7	3	5	26
39	Hungary	0	1	5	0	0	0	0	0	1	0	0	2	2	0	1	2	2	1	2	5	0	0	24
40	Norway	0	0	2	0	1	2	0	1	0	1	0	0	1	1	1	0	1	0	4	4	3	2	24

Abbreviations: D1, D2 and D3 = Number of publications in 1968–1977, 1978–1987, 1988–1997. The rest of years indicate the number of publications in that year.

Table 11
Publication structure classified by supranational regions.

R	Country	TP	TC	H	C/P	≥ 250	≥ 100	≥ 50	P/Pop	C/Pop
1	East Asia	3410	57,409	89	16,84	9	71	252	2,13	35,84
2	North America	1836	39,121	66	21,31	14	41	108	5,32	113,33
3	Western Europe	1806	31,487	72	17,43	12	42	131	4,32	75,33
4	Rest of Asia	576	9520	46	16,53	1	5	39	0,22	3,72
5	Eastern Europe	417	9235	39	22,15	7	14	31	0,99	21,83
6	Middle East	385	5464	37	14,19	1	6	23	1,04	14,73
7	Oceania	337	4589	33	13,62	0	5	16	9,19	125,18
8	Latin America	296	4483	35	15,15	0	7	24	0,47	7,15
9	Africa	105	1461	17	13,91	1	2	6	0,09	1,22

Abbreviations available in previous tables except: P/Po and C/Po = Papers and cites per million inhabitants.

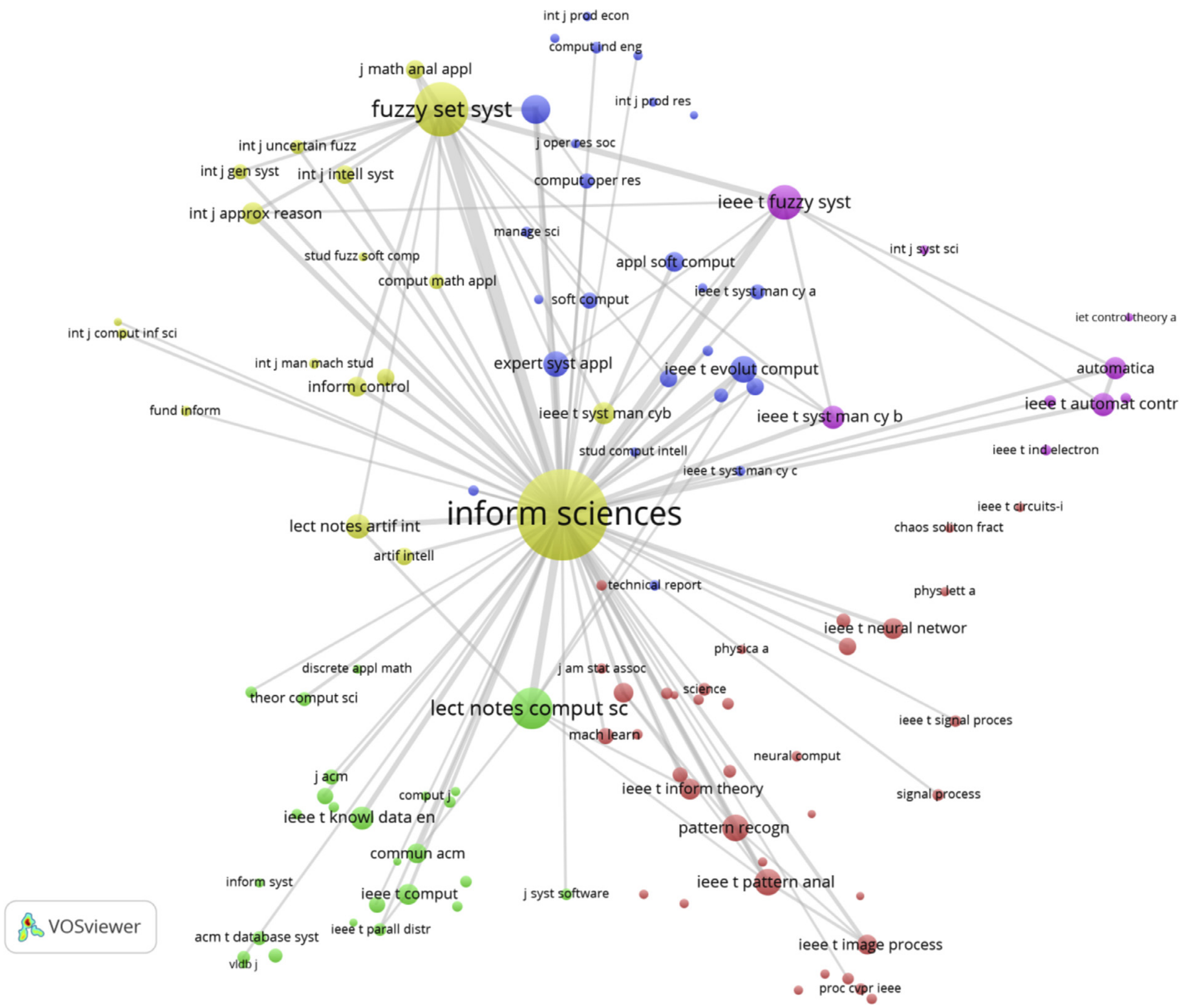

Fig. 2. Co-citation of journals cited in IS.

4. Graphical analysis of Information Sciences with VOS viewer

The previous section provides a general overview of the most productive and influential variables in the journal. In this section, in order to provide a deeper analysis of the publication structure, let us visualize the bibliographic connections between the leading sources. For doing so, the work uses the VOS viewer software [39] collecting the bibliographic data and generating graphical maps by using bibliographic coupling, citation and co-citation analysis, co-authorship, and co-occurrence of author keywords [27]. First, let us analyze co-citation of journals cited in Information Sciences. Recall, that

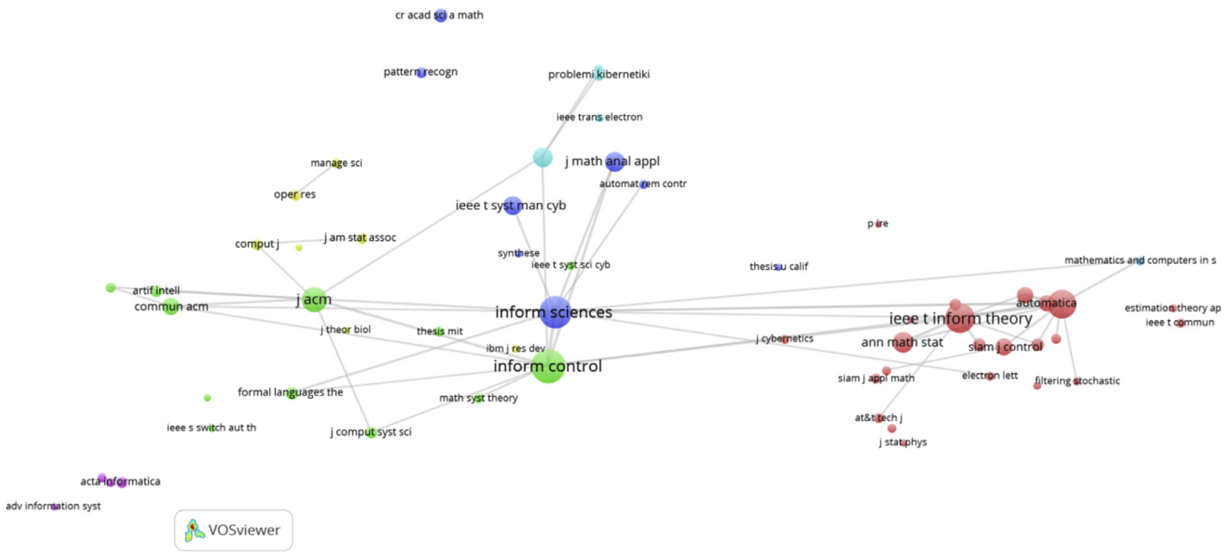

Fig. 3. Co-citation of journals cited in IS: 1968–1979.

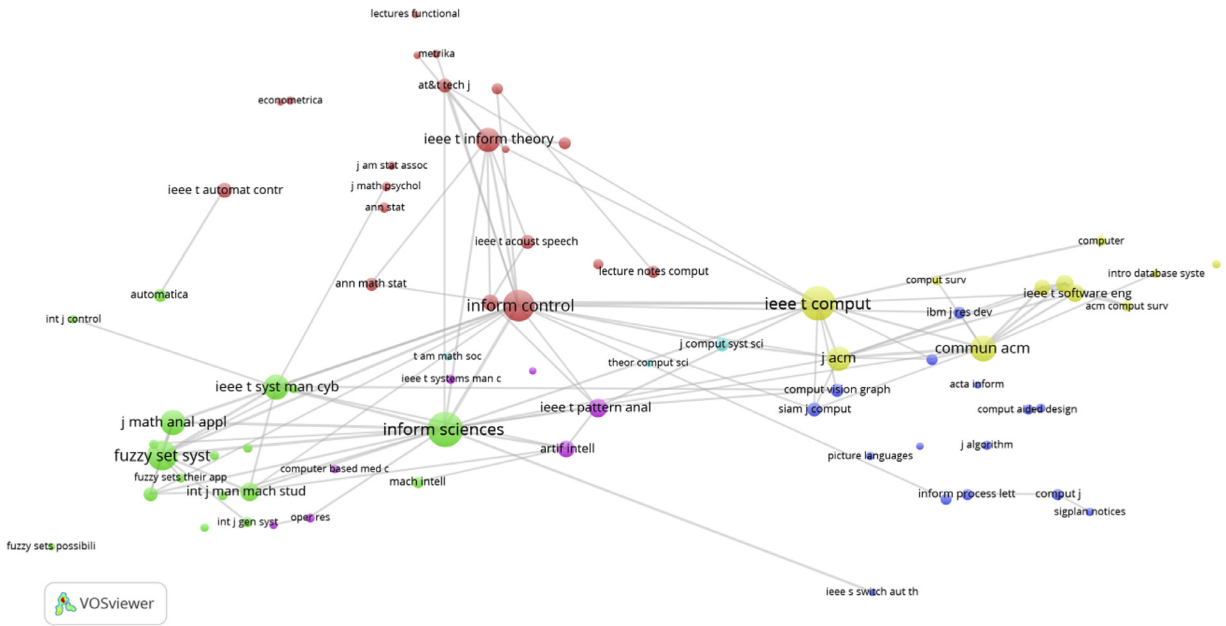

Fig. 4. Co-citation of journals cited in IS: 1980–1989.

co-citation occurs when two documents published in different journals receive a citation from a third document of another journal. Fig. 2 presents the general visualization between 1968 and 2016 with a minimum threshold of two hundred cites and the one hundred most representative connections. Note that the colors of the circles of the journals indicate the cluster to which the journals belong.

The self-citations of Information Sciences dominate the map, which is very common for the majority of journals. Moreover, note that Information Sciences is a big journal, which implies a huge potential for citing other papers published therein. Computer science journals are the most influential ones including the IEEE Transactions on Fuzzy Systems and Fuzzy Sets and Systems. Note that the Lecture Notes on computer science are also very influential in the journal. In order to see how the citations evolve through time, Fig. 3–7 present the co-citation of journals between 1968–1979, 1980–1989, 1990–1999, 2000–2009 and 2010–2016. Note that the thresholds for these figures are five, ten, twenty, twenty-five, and one hundred, respectively. The co-citation networks in the figures are one hundred excepting the first figure (1968–1979) that has fifty.

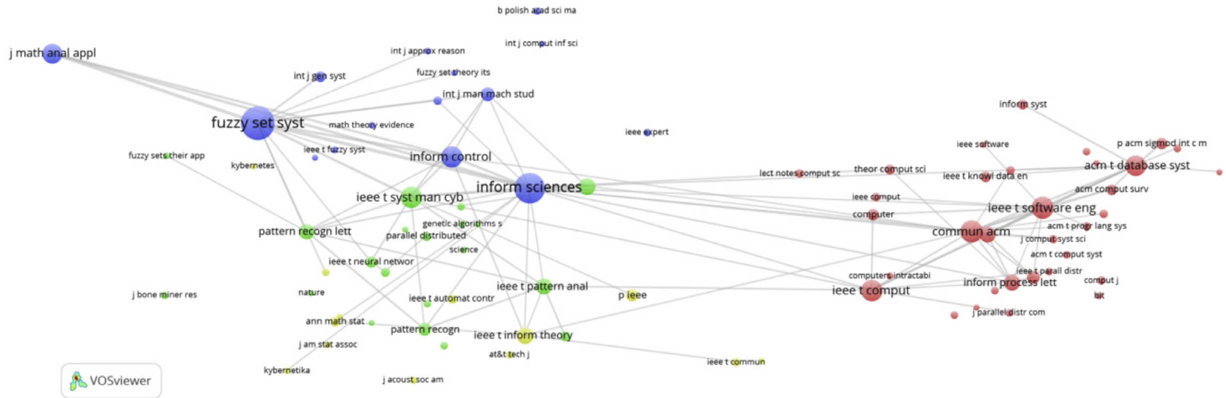

Fig. 5. Co-citation of journals cited in IS: 1990–1999.

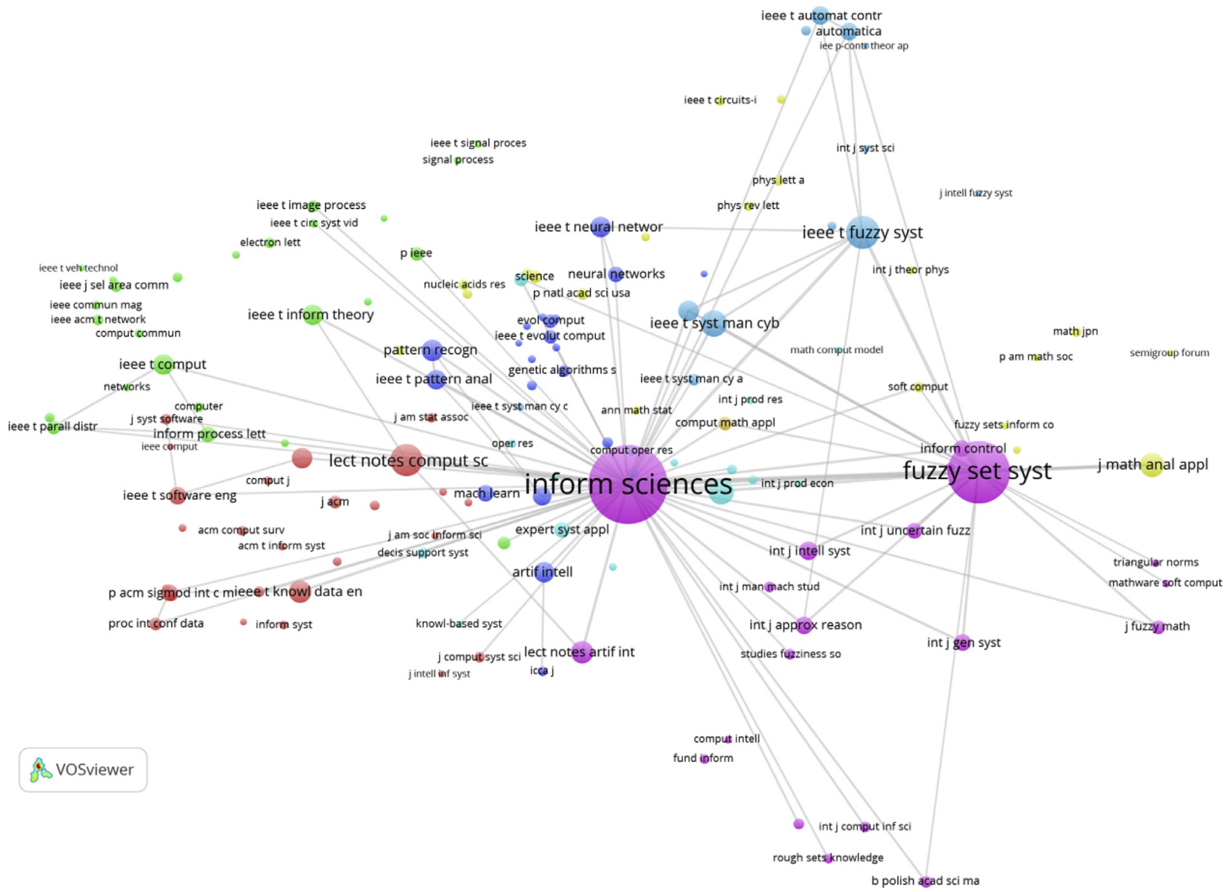

Fig. 6. Co-citation of journals cited in IS: 2000–2009.

At the beginning, the journal did not have many self-citations because there were not many previous papers to be cited. In the seventies and eighties, there were not as many journals as today and the papers published in the journal were less than today. Therefore, the graphical map is less dense than the other ones. Note that the thresholds used in these figures are higher for the newer sets of documents so their figures would be much denser if using the same threshold. Through time, the self-citations of Information Sciences are becoming more relevant and mainly connected to computer science journals.

In order to summarize these results and identify the most relevant ones, Table 12 presents the forty most cited journals in Information Sciences considering the total results and four periods: 1968–1989, 1990–1999, 2000–2009 and 2010–2016.

Table 12
Most cited journals in IS.

R	Global Journal	Cit	CLS	2010–2016 Journal	Cit	CLS	2000–2009 Journal	Cit	CLS	1990–1999 Journal	Cit	CLS	1968–1989 Journal	Cit	CLS
1	Inform Sciences	21,702	15,020.07	Inform Sciences	16,521	11,782.88	Inform Sciences	2718	1907.82	Fuzzy Set Syst	599	393.56	Inform Sciences	277	211.65
2	Fuzzy Set Syst	7703	5448.79	Fuzzy Set Syst	4339	3327.50	Fuzzy Set Syst	1732	1171.68	Inform Sciences	483	390.60	Inform Control	248	196.97
3	IEEE T Fuzzy Syst	3230	2652.48	IEEE T Fuzzy Syst	2500	2088.89	IEEE T Fuzzy Syst	488	394.76	IEEE T Software Eng	266	193.81	IEEE T Comput	213	110.68
4	Eur J Oper Res	2268	1928.92	Eur J Oper Res	1805	1545.15	IEEE T Syst Man Cyb	304	279.11	Commun ACM	253	215.98	IEEE T Inform Theory	166	119.59
5	IEEE T Pattern Anal Mach	1880	1609.98	IEEE T Evolut Comput	1713	1382.64	Eur J Oper Res	282	241.00	IEEE T Syst Man Cyb	243	210.73	J ACM	142	117.65
6	IEEE T Evolut Comput	1842	1448.14	Expert Syst Appl	1616	1472.81	J Math Anal Appl	260	210.97	Inform Control	238	215.08	Fuzzy Set Syst	132	101.06
7	Pattern Recogn	1817	1592.36	IEEE T Pattern Anal Mach	1443	1268.32	IEEE T Knowl Data En	230	196.03	IEEE T Comput	236	173.79	J Math Anal Appl	132	98.87
8	Expert Syst Appl	1772	1595.08	Pattern Recogn	1427	1277.50	Pattern Recogn	208	172.05	ACM T Database Syst	230	177.24	Commun ACM	130	103.86
9	IEEE T Syst Man Cy B	1438	1361.61	IEEE T Syst Man Cy B	1148	1098.33	IEEE T Syst Man Cy B	193	180.32	J Math Anal Appl	210	163.98	IEEE T Syst Man Cyb	126	95.87
10	IEEE T Knowl Data En	1420	1278.06	Int J Approx Reason	1093	1002.62	Artif Intell	190	156.85	Artif Intell	152	102.55	IEEE T Automat Contr	104	70.23
11	IEEE T Automat Contr	1412	1066.95	Appl Soft Comput	1023	965.32	IEEE T Neural Networ	188	160.91	IEEE T Inform Theory	148	90.09	Ann Math Stat	62	48.03
12	Int J Approx Reason	1311	1201.50	IEEE T Knowl Data En	1018	934.78	IEEE T Inform Theory	186	120.27	IEEE T Pattern Anal Mach	143	115.36	Artif Intell	57	43.62
13	Automatica	1265	1042.39	IEEE T Automat Contr	978	796.86	IEEE T Comput	184	133.12	J ACM	143	128.28	Int J Man Mach Stud	55	44.53
14	IEEE T Syst Man Cyb	1232	1106.35	Automatica	964	819.83	Commun ACM	183	161.16	Inform Process Lett	134	109.34	IEEE T Pattern Anal Mach	54	47.31
15	IEEE T Neural Networ	1158	1018.57	IEEE T Image Process	936	778.84	IEEE T Pattern Anal Mach	182	152.65	Pattern Recogn Lett	121	89.66	Automatica	52	43.09
16	IEEE T Inform Theory	1132	774.06	IEEE T Neural Networ	812	739.15	Pattern Recogn Lett	162	145.57	Int J Man Mach Stud	99	84.93	P IEEE	51	47.16
17	IEEE T Comput	1108	776.83	Knowl-Based Syst	770	727.51	IEEE T Automat Contr	151	107.22	SIAM J Comput	95	84.06	IEEE T Software Eng	47	37.35
18	Commun ACM	1077	927.42	Pattern Recogn Lett	700	664.85	Int J Intell Syst	150	141.53	Pattern Recogn	92	78.82	ACM T Database Syst	46	37.70
19	Inform Control	1057	915.11	Neurocomputing	669	631.75	Int J Approx Reason	147	138.87	P IEEE	81	75.73	AT&T Tech J	41	32.25
20	Appl Soft Comput	1053	987.57	Appl Math Comput	637	599.65	IEEE T Software Eng	141	87.28	IEEE T Neural Networ	74	59.59	J Comput Syst Sci	41	36.55
21	Pattern Recogn Lett	1051	954.81	Int J Intell Syst	633	598.81	Automatica	136	114.88	Computer	69	63.10	Int J Control	36	30.59
22	IEEE T Image Process	1036	845.88	Soft Comput	597	569.02	Inform Control	131	127.40	Int J Gen Syst	62	53.16	IEEE T Acoust Speech	34	18.52
23	J Math Anal Appl	965	797.54	Mach Learn	571	531.37	Int J Gen Syst	128	119.58	ACM Comput Surv	60	55.11	SIAM J Comput	34	31.08
24	Int J Intell Syst	904	850.90	J Mach Learn Res	555	516.27	Mach Learn	125	110.49	IEEE T Knowl Data En	59	53.66	IEEE T Commun	32	22.15
25	Artif Intell	862	708.88	IEEE T Syst Man Cy A	518	474.76	Expert Syst Appl	119	99.22	Comput Vision Graph	58	45.24	Comput J	30	23.32
26	Knowl-Based Syst	810	762.74	Comput Oper Res	511	472.25	Inform Process Lett	118	101.48	Ann Math Stat	57	47.88	IBM J Res Dev	29	25.51
27	Appl Math Comput	771	715.26	IEEE T Inform Theory	504	407.14	Int J Uncertain Fuzz	110	103.07	Theor Comput Sci	56	49.45	Comput Vision Graph	28	25.56
28	Neurocomputing	767	720.50	IEEE T Syst Man Cyb	456	446.48	Neural Networks	109	94.10	Inform Syst	55	51.00	Mach Intell	28	25.64
29	Mach Learn	751	681.28	Commun ACM	429	413.60	P IEEE	87	77.12	Neural Networks	50	41.56	SIAM J Control	28	19.35
30	Soft Comput	685	651.01	Artif Intell	416	386.86	Comput Math Appl	86	81.02	IEEE T Automat Contr	44	33.01	Int J Comput Math	27	25.21
31	Inform Process Lett	684	573.34	Comput Math Appl	415	390.91	J Fuzzy Math	86	75.90	Comput J	42	35.95	Pattern Recogn	27	22.11
32	IEEE T Software Eng	682	476.46	IEEE T Comput	386	330.05	IEEE T Evolut Comput	84	65.20	IEEE T Commun	42	31.95	Oper Res	25	18.68
33	J ACM	627	524.65	Theor Comput Sci	385	355.10	Appl Math Comput	83	74.67	J Comput Syst Sci	42	40.67	Art Computer Program	23	20.33
34	IEEE T Syst Man Cy A	623	569.71	Evol Comput	384	361.53	IEEE T Parall Distr	83	67.73	Comput Surv	41	40.52	Inform Process Lett	23	21.87
35	Int J Gen Syst	614	583.34	Int J Uncertain Fuzz	378	368.65	Evol Comput	82	73.05	ACM T Progr Lang Sys	38	35.02	J Am Stat Assoc	21	17.20
36	Comput Oper Res	600	551.98	Science	360	344.70	Theor Comput Sci	80	72.81	Int J Intell Syst	38	35.52	Comm ACM	20	11.38
37	J Mach Learn Res	590	543.81	Int J Gen Syst	346	337.67	Science	71	64.37	Acta Inform	37	34.41	Manage Sci	20	19.00
38	Comput Math Appl	575	538.88	Comput Ind Eng	340	325.33	J ACM	70	66.01	IEEE Comput	37	35.60	ACM Comput Surv	19	17.56
39	Theor Comput Sci	559	509.33	Neural Networks	339	314.13	ACM T Database Syst	69	60.74	J Acoust Soc Am	36	12.74	Ann Stat	18	12.70
40	Int J Uncertain Fuzz	540	519.47	Int J Innov Comput I	338	319.27	IEEE T Syst Man Cy A	66	64.68	J Bone Miner Res	36	4.50	Int J Gen Syst	18	17.81

Abbreviations: Cit = Total citations received in IS; CLS = Co-citation links.

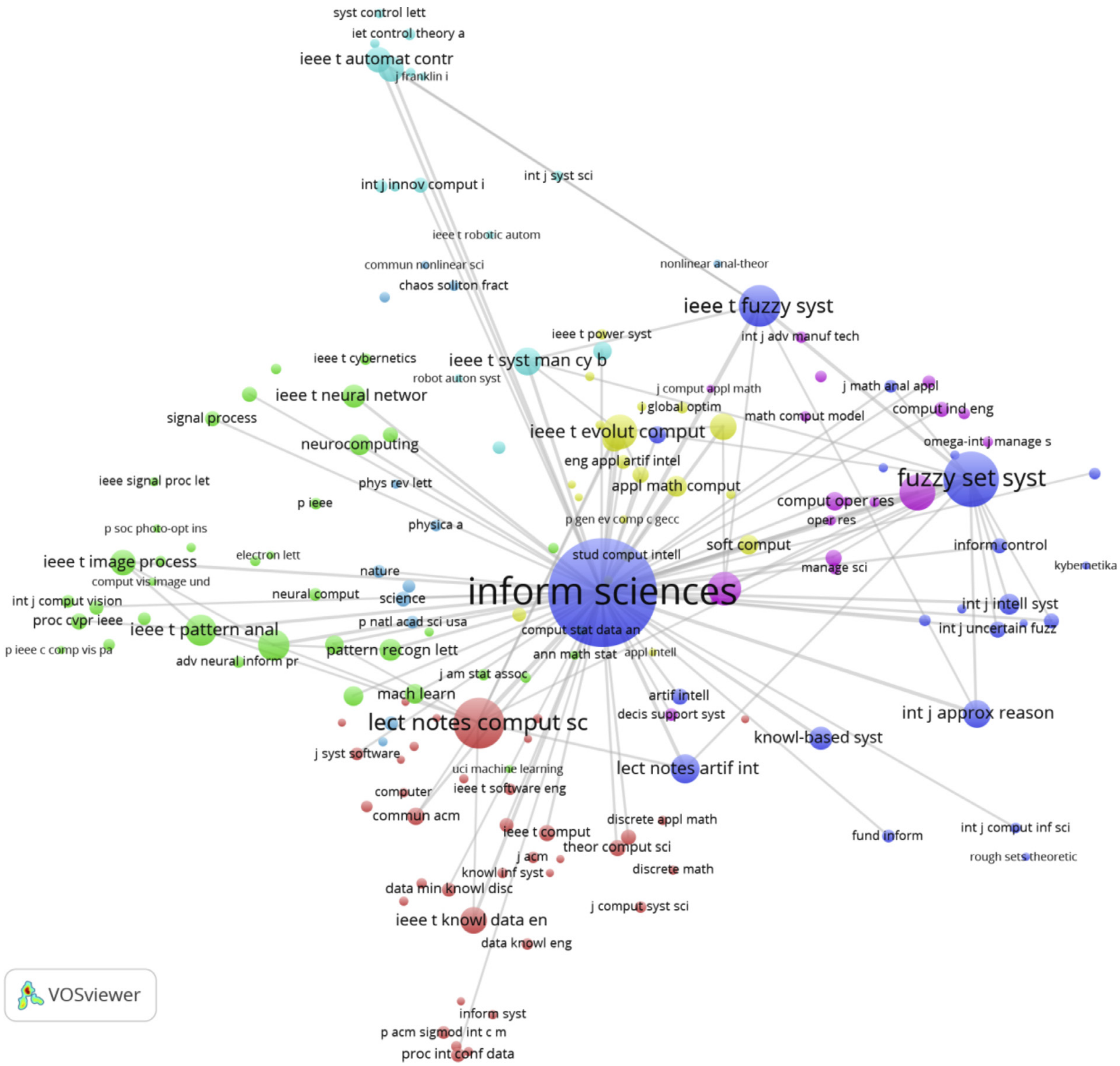

Fig. 7. Co-citation of journals cited in IS: 2010–2016.

The results show the strong influence of Information Sciences through time followed by Fuzzy Sets and Systems. Note that many IEEE journals are very relevant in the journal including the IEEE Transactions on Fuzzy Systems, IEEE Transactions on Pattern Analysis and Machine Intelligence, and IEEE Transactions on Evolutionary Computation.

Next, let us analyze bibliographic coupling of authors that publish in the journal. Recall that bibliographic coupling [22] of authors occurs when the authors of two documents cite the same third document. Fig. 8 presents the most productive authors with a threshold of ten documents published and the one hundred strongest bibliographic coupling links between authors.

The results are in accordance with Table 5. The advantage of this figure is the graphical mapping of authors that connects or clusters together those that have similar research profiles. That is, those that cite similar bibliographic material.

Next, let us look into the bibliographic coupling of institutions publishing in the journal. Fig. 9 visualizes the data considering a minimum threshold of twenty documents and one hundred connections.

The leading institutions are consistent with those of Table 7. An interesting result here is that the universities from the same country tend to have a similar profile between them, often clustered together and with strong connections.

Observe that the bibliographic data of institutions depends on the authors working at these organizations. In order to deepen in the analysis, let us present a graphical visualization of the citations between institutions. In order to do so, Fig. 10 shows the results with the same threshold and connections as Fig. 9.

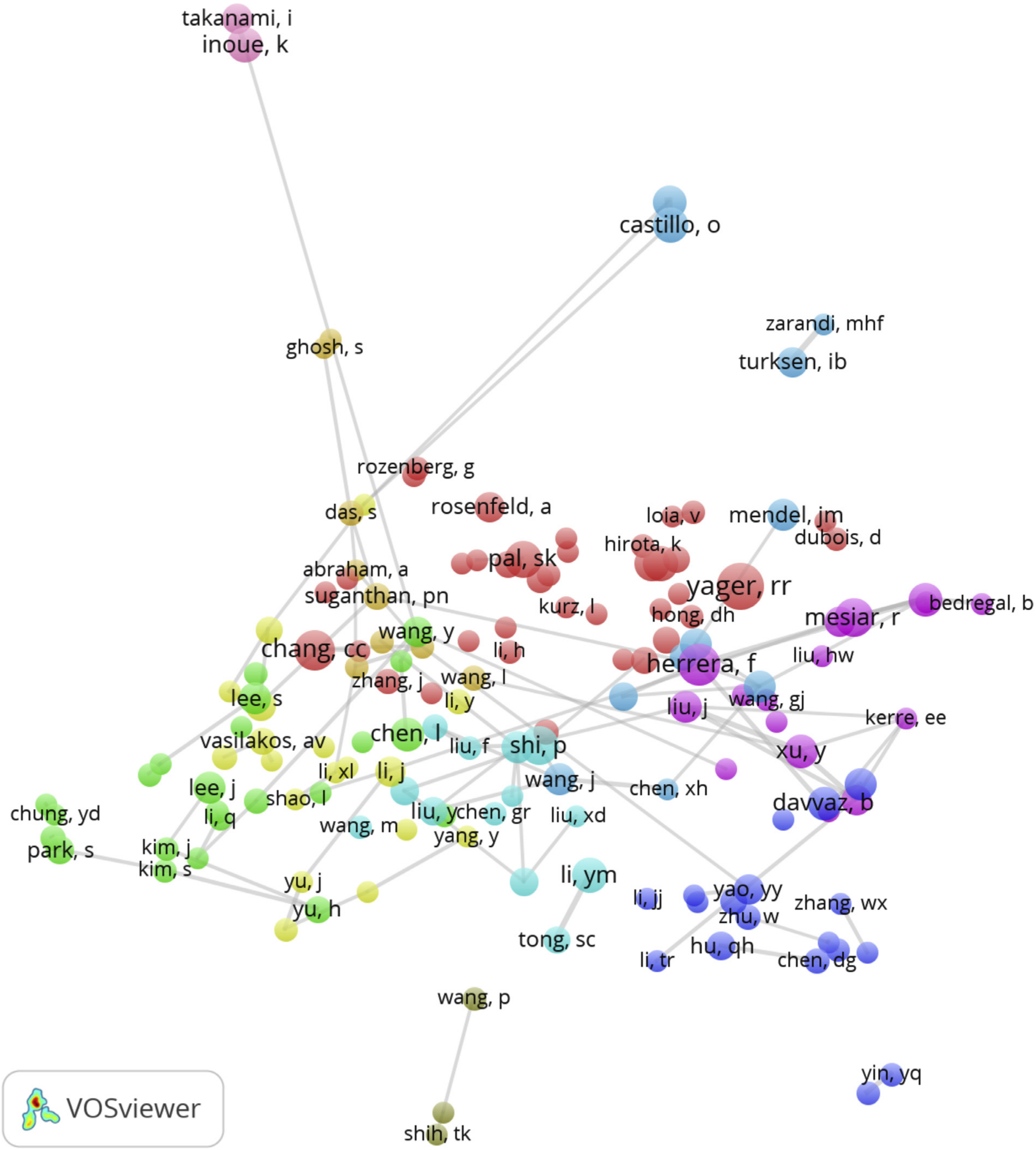

Fig. 8. Bibliographic coupling of authors that publish in IS.

The results are equivalent to the results already displayed in Fig. 9 with the institutions from the same country citing each other much more than with foreign countries. Note that the densest network is for China although the rest of the countries show a similar tendency.

Another interesting issue is to study co-authorship of institutions, i.e. how the authors of different organizations publish together. Fig. 11 presents co-authorship of institutions with the same threshold and connections as Figs. 9 and 10.

The results are similar to those of the previous figures. However, here the connections between institutions of the same country are stronger which clearly indicates that authors from the same country tend to collaborate more than with foreign authors.

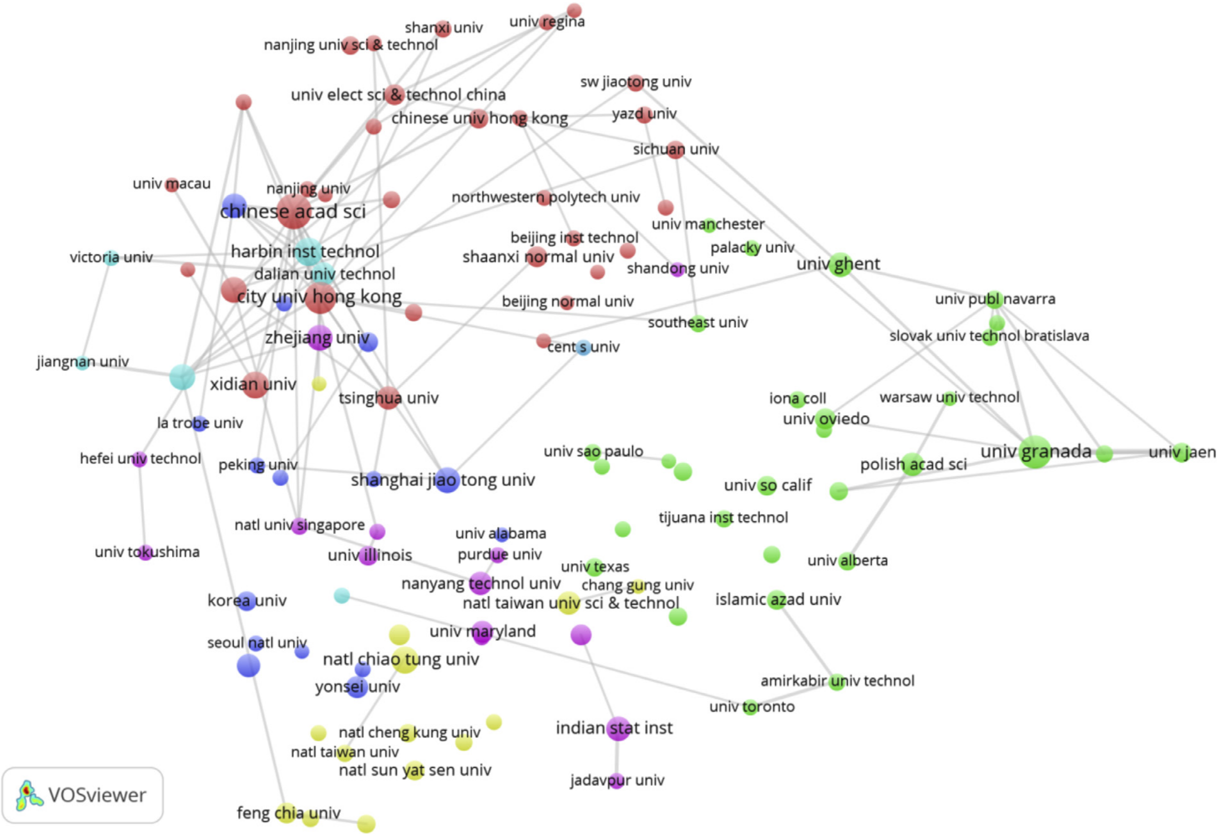

Fig. 9. Bibliographic coupling of institutions that publish in IS.

In order to summarize the results at the country level, Fig. 12 presents bibliographic coupling of countries with a threshold of five documents and one hundred connections.

The results are in accordance with Table 9 where China is the most productive country followed by the USA. At this level, the data is quite diverse with countries from different regions linked together.

Finally, let us analyze the leading keywords of the journal. For doing so, the study considers co-occurrence of author keywords. Fig. 13 visualizes the map considering a threshold of twenty occurrences and the one hundred most representative connections.

Data mining, classification, fuzzy and rough sets, genetic algorithms, and particle swarm optimization, are the most frequent keywords in the journal. In order to see how the use of these keywords is evolving through time, Table 13 presents the Top 40 occurrences of the author keywords divided in three periods: 1990–1999, 2000–2009 and 2010–2016.

During the last years, particle swarm optimization is becoming the most frequent keyword. However, if we unify singular and plural terms, then, rough sets and genetic algorithms would be more common. At the beginning of the new millennium, fuzzy set theory was the leading topic followed by genetic algorithms, rough sets and neural networks.

5. Summary and conclusions

In 2018, Information Sciences celebrates the 50th anniversary. Due to this, the paper presents a bibliometric analysis of the journal during this period in order to identify the most significant results occurring in the journal. The work searches for all the publications of Information Sciences between 1968 and 31 December 2016, by using the Web of Science Core Collection database. The results provide a general overview of the journal's leading trends and show the strong impact the journal has in the scientific community. Particularly, it is worth noting that the most cited paper of the journal is among the fifty most cited papers of all-time in computer science [46,48].

Information Sciences is a global international journal with publications from all over the world. The journal has a similar publication profile than other journals in the field such as Fuzzy Sets and Systems and the International Journal of Intelligent Systems [26]. Information Sciences shows a strong influence by fuzzy and rough set theory although it publishes a wide range of results regarding information, knowledge engineering, intelligent systems and applications connected to these fields.

It is worth noting that China has become the most productive country in the journal with an annual number of papers well above the rest of the countries. Several of its institutions are among the most productive ones in the journal including

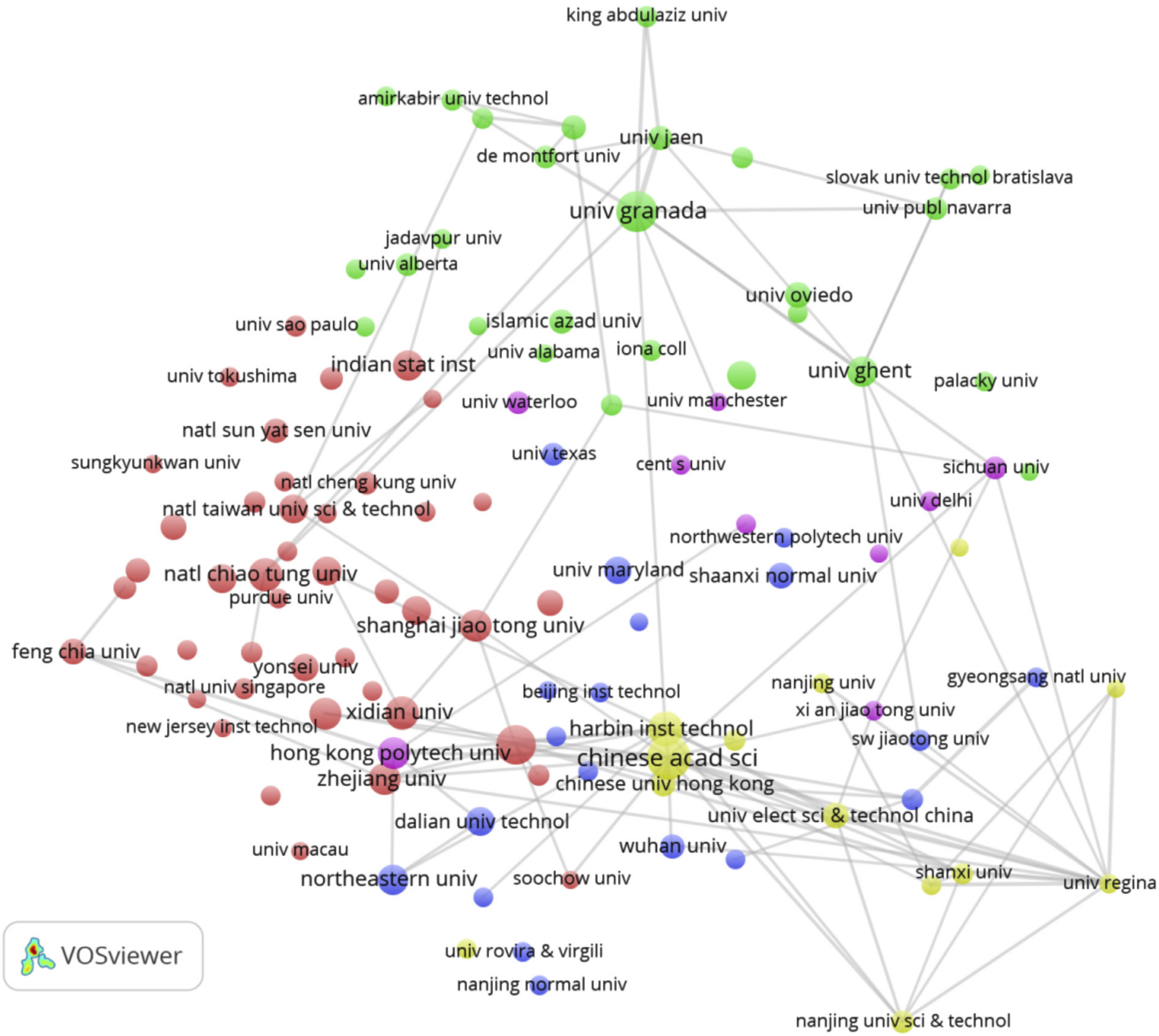

Fig. 10. Citation analysis of institutions publishing in IS.

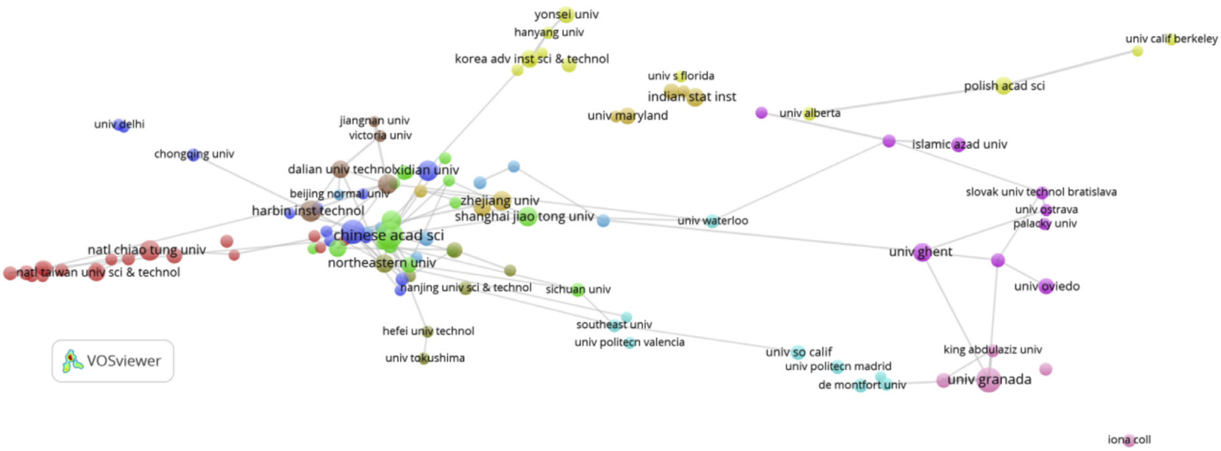

Fig. 11. Co-authorship of institutions that publish in IS.

Table 13
Most common author keyword occurrences in IS.

	Global			2010–2016			2000–2009			1990–1999		
R	Keyword	Oc	Co	Keyword	Oc	Co	Keyword	Oc	Co	Keyword	Oc	Co
1	Data mining	104	46	Particle swarm optimization	83	41	Fuzzy sets	43	17	Rough sets	12	9
2	Classification	100	48	Classification	70	31	Genetic algorithms	30	19	Neural networks	9	6
3	Fuzzy sets	93	44	Rough set	60	28	Rough sets	29	23	Algorithms	6	2
4	Genetic algorithm	92	44	Data mining	56	22	Data mining	27	17	Fuzzy logic	6	3
5	Particle swarm optimization	87	39	Genetic algorithm	55	29	Genetic algorithm	22	14	Fuzzy sets	5	4
6	Rough sets	84	47	Clustering	46	21	Fuzzy logic	21	11	Data mining	4	2
7	Rough set	83	32	Feature selection	42	31	Neural network	21	11	Genetic algorithm	4	3
8	Fuzzy logic	77	37	Optimization	40	28	Classification	19	15	Approximation operators	3	3
9	Genetic algorithms	70	39	Granular computing	38	30	Neural networks	18	11	Concurrency control	3	1
10	Clustering	68	25	Scheduling	37	21	Clustering	17	8	Graph theory	3	1
11	Optimization	66	34	Evolutionary computation	36	23	Fuzzy number	15	5	Information retrieval	3	0
12	Feature selection	56	39	Fuzzy logic	36	19	Optimization	15	9	Information theory	3	1
13	Fuzzy set	55	33	Machine learning	35	24	Rough set	15	5	Knowledge discovery	3	3
14	Machine learning	54	27	Swarm intelligence	35	26	Genetic programming	14	7	Machine learning	3	2
15	Neural networks	51	28	Differential evolution	34	22	Feature selection	13	10	Object-oriented databases	3	0
16	Granular computing	50	34	Fuzzy set	33	19	Fuzzy control	13	6	Optimization	3	2
17	Neural network	50	25	Multi-objective optimization	32	20	Cryptography	12	2	Pattern recognition	3	3
18	Uncertainty	49	30	Rough sets	32	19	Machine learning	12	7	Relational databases	3	2
19	Evolutionary computation	44	28	Genetic algorithms	31	20	Uncertainty	12	10	Segmentation	3	1
20	Genetic programming	43	17	Uncertainty	31	15	Fuzzy numbers	11	4	Uncertainty	3	2
21	Scheduling	43	11	Evolutionary algorithm	30	22	Fuzzy set	11	6	ATM	2	0
22	Multi-objective optimization	40	24	Evolutionary algorithms	29	15	Pattern recognition	10	7	Backpropagation	2	1
23	Cryptography	38	4	Interconnection network	28	9	Convergence	9	4	Classification	2	2
24	Differential evolution	38	22	Fuzzy sets	27	19	Hypercube	9	5	Closure property	2	1
25	Evolutionary algorithms	38	17	Collaborative filtering	26	16	Approximation operators	8	8	Decision rules	2	2
26	Fuzzy number	38	5	Attribute reduction	25	15	Artificial immune system	8	3	Distributed computing	2	1
27	Swarm intelligence	37	19	Group decision making	25	11	Association rules	8	5	Dynamic programming	2	1
28	Attribute reduction	36	21	Recommender system	25	17	Computing with words	8	6	Expert systems	2	1
29	Interconnection network	36	13	Support vector machine	25	8	Fuzzy relation	8	5	Extension principle	2	1
30	Entropy	33	18	Aggregation function	24	13	Fuzzy systems	8	5	Fuzzy databases	2	0
31	Rough set theory	33	18	Similarity measure	24	16	Information retrieval	8	4	Fuzzy modeling	2	2
32	Fuzzy numbers	32	7	Entropy	23	15	Knowledge discovery	8	3	Fuzzy models	2	0
33	Group decision making	32	13	Genetic programming	22	11	Ontology	8	1	Fuzzy neural networks	2	2
34	Evolutionary algorithm	31	22	Global optimization	22	12	Rough set theory	8	3	Fuzzy number	2	1
35	Collaborative filtering	30	15	Rough set theory	22	15	Similarity	8	5	Genetic algorithms	2	1
36	Decision making	30	15	Intuitionistic fuzzy set	21	13	Simulation	8	6	Genetic programming	2	0
37	Fuzzy control	30	14	Neural network	21	11	Triangular norm	8	4	Group decision making	2	1
38	Similarity measure	30	20	Cryptography	20	5	Approximate reasoning	7	6	Hypercube	2	0
39	Pattern recognition	29	20	Decision making	20	10	Attribute reduction	7	3	Incomplete information systems	2	2
40	Fuzzy clustering	28	10	Fuzzy clustering	20	7	Bioinformatics	7	2	Knowledge acquisition	2	2

Abbreviations: Oc = Author keyword occurrences; Co = Author keyword co-occurrences links.

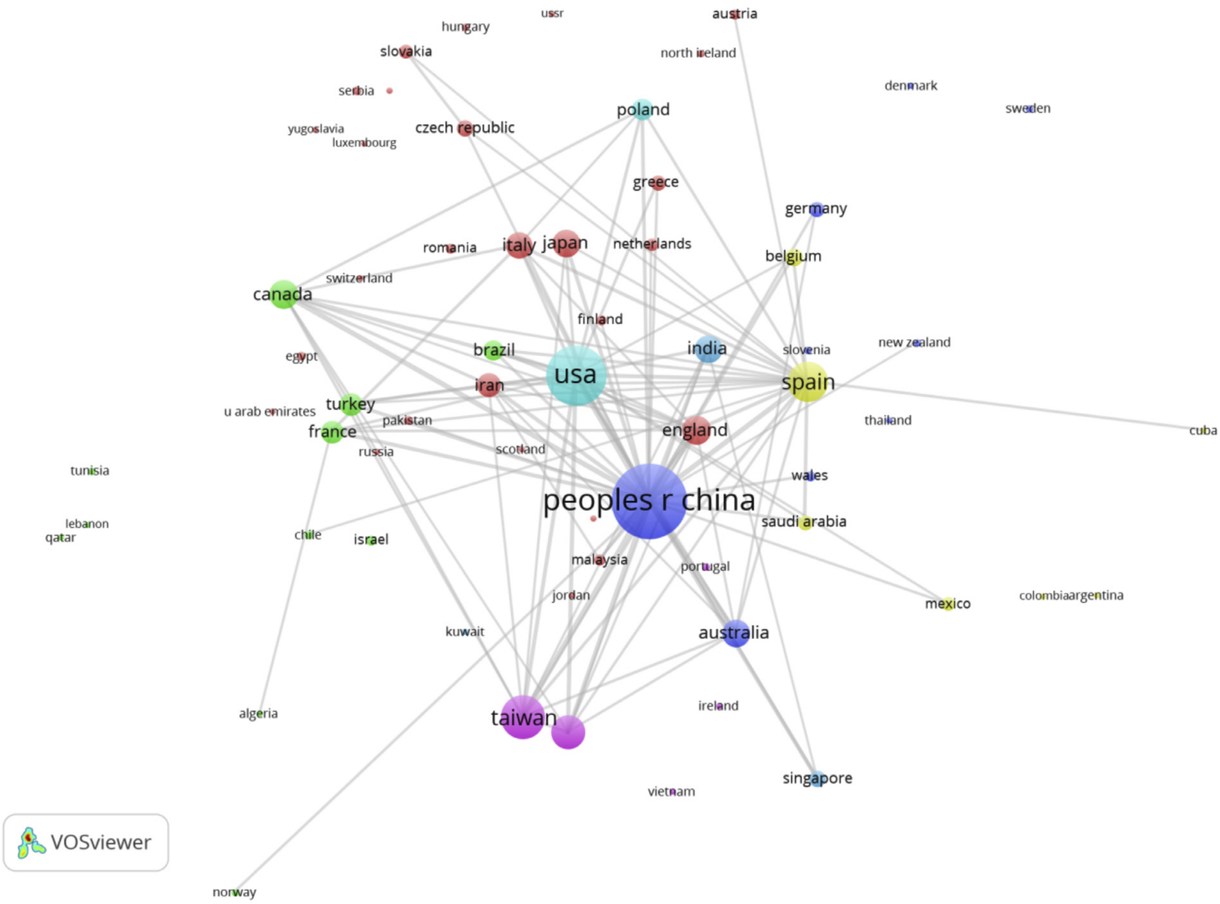

Fig. 12. Bibliographic coupling of countries that publish in IS.

the Chinese Academy of Sciences, the City University of Hong Kong and Xidian University. Several authors are performing well including Zeshui Xu and Yingming Li. Note that more than half of the fifty most productive institutions are from East Asia, mainly from China and Taiwan.

The USA has the most cited papers thanks to Zadeh but its productivity is decreasing significantly publishing today only 10% of the papers of the journal. Spain is the only European country performing well according to its standards having six institutions on the Top 50, including the University of Granada that obtains the second position. Belgium, Czech Republic and Slovakia also obtain remarkable results according to their size. Some authors from this region also appear well placed in the ranking including Francisco Herrera and Radko Mesiar. Some Latin American, Middle East and African countries appear among the fifty most productive ones but far away from the top.

In order to deepen the bibliometric results, the study also develops a graphical visualization of the results by using the VOS viewer software. The work shows the publication structure of authors, institutions, and countries, by using bibliographic coupling, co-authorship and citation analysis. The results are in accordance with those of Section 3 where China is currently holding the most significant position in the journal. The software also visualizes the most cited journals in Information Sciences through co-citation analysis. The self-citations of the journal are the most relevant ones, which is very common in the majority of journals. Most of the journals cited are connected to computer science and engineering. The graphical analysis ends with a mapping of the most frequent keywords and the co-occurrence between them. The leading topics of the journal is connected to data mining, fuzzy and rough set theory, genetic algorithms and particle swarm optimization.

Note that this study provides a general overview of the publications of the journal with the aim of being informative and identifying the leading trends. However, observe that these results come from the Web of Science Core Collection database. Although this database is usually regarded as one of the most influential ones for classifying research, it may have some limitations. First, it uses full counting to all the participating units of a paper. Therefore, papers with several co-authors obtain better results than single-author papers because their results are not fractioned according to the number of authors. Second, popular topics usually obtain more cites than less popular topics although this does not imply that the research is more relevant. Popularity is a good indicator of influence. However, there are many exceptional situations that may produce deviations in this result. Third, the analysis measures the publications considering the authors that publish in the journal

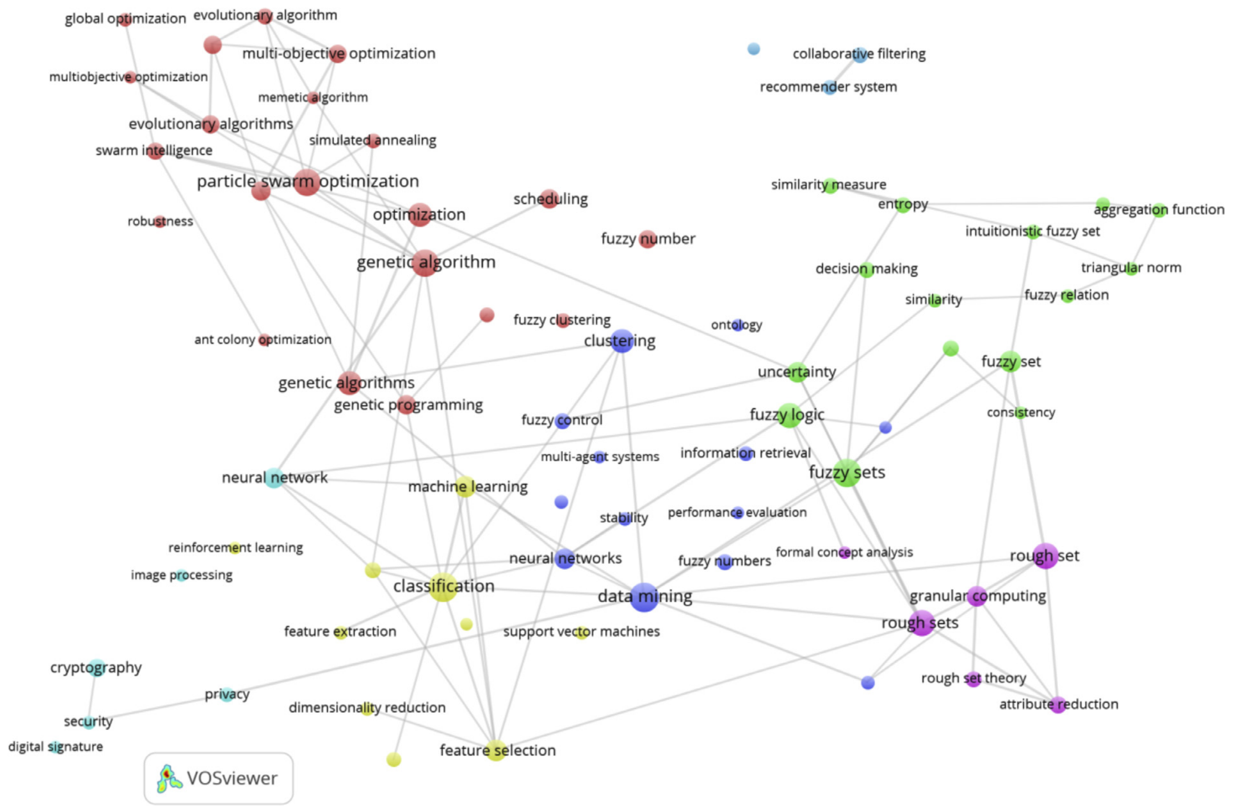

Fig. 13. Co-occurrence of author keywords of documents published in IS.

and their affiliation (institution and country) at the time of publication. However, note that many authors have changed institution through time so the results show the data at the time of publication although today the author may be working at another institution. Finally, the results of the paper represent the general picture available up to 2017. In the future, these results may change because the bibliometric data is dynamic and may evolve differently and with many unexpected additions.

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