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FOUNDATIONS

Twenty years of Soft Computing: a bibliometric overview

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Abstract
The journal Soft Computing was launched in 1997, and it is dedicated to promote advancements in soft computing theories, which includes fuzzy sets theory, neural networks, evolutionary computation, probabilistic reasoning and hybrid theories. 2017 marks the 20th anniversary of the journal. Motivated by this anniversary, this study presents a bibliometric analysis of the current publications in the journal in order to identify the leading trends ruling the journal. The paper also develops a mapping analysis of the bibliographic material by using the visualization of similarities viewer software. The results show that researchers from all over the world publish regularly in the journal. Soft Computing is growing significantly during the last years, becoming one of the leading journals in the field.

Keywords Bibliometrics · Web of Science · h-Index · VOS viewer

1 Introduction

The Soft Computing (SC) journal is a leading international journal in the field of Soft Computing, which encompasses a wide range of theories including fuzzy sets and systems, neural networks, evolutionary computation, probabilistic reasoning and other related theories. The journal published its first issue in 1997, and since then, it has increased significantly becoming today a monthly journal. The journal is indexed in Web of Science Core Collection and received an impact factor of 2.472 in the latest Journal Citation Reports being in the 46th position of 133 journals in the category of Computer Science, Artificial Intelligence. Antonio Di Nola, the founding editor-in-chief, created the journal. Today, he currently runs the journal together with Vincenzo Loia. Both are from the University of Salerno, Italy. SC is published by Springer international publisher.

In 2017, SC has celebrated 20 years old. To mark this anniversary, this work presents a bibliometric overview of the journal in order to identify the leading trends that have occurred over the last 20 years. The study identifies the most productive authors, institutions and countries and develops a general analysis of the publications and citations of the journal. The work also develops a mapping analysis in order to visualize the bibliographic material by using the visualization of similarities (VOS) viewer software (Van Eck and Waltman 2010). The analysis uses a wide range of bibliometric indicators including the number of papers and citations, the h-index (Hirsch 2005), citation thresholds, bibliographic coupling (Kessler 1963) and co-citation (Small 1973).

Observe that many other journals have already developed a bibliometric overview of their journals, especially for the celebration of a special event. Among others, it is worth mentioning:

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- Journal of Financial Economics (Schwert 1993).
- Strategic Management Journal (Ramos-Rodríguez and Ruiz-Navarro 2004).
- Technovation (García-Merino et al. 2006).
- Journal of Risk and Insurance (Weiss and Qiu 2008).
- Knowledge-Based Systems (Cobo et al. 2015).
- Journal of Business Research (Merigó et al. 2015b).
- International Journal of Intelligent Systems (Merigó et al. 2017).
- Journal of Business & Industrial Marketing (Valenzuela et al. 2017).
- European Journal of Operational Research (Laengle et al. 2017).
- Computers & Industrial Engineering (Cancino et al. 2017b).
- Information Sciences (Merigó et al. 2018; Yu et al. 2017).
- Journal of Political Economy (Amiguet et al. 2017).
- European Journal of Marketing (Martínez-López et al. 2018).
- International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems (Wang et al. 2018).
- International Journal of Fuzzy Systems (Tang et al. 2018).

The remainder of the work is structured as follows: Section 2 presents the bibliometric methods to be used in the paper. Section 3.1 presents the most productive authors, institutions and countries. Section 3.2 studies the structure of the publications and citations of the journal. Section 4 presents the graphical analysis with VOS viewer software. Section 5 summarizes the main findings and conclusions of the study.

2 Bibliometric methods

The work uses different bibliometric methods to discover information from the journal Soft Computing (Gutierrez-Salcedo et al. 2018). Observe that bibliometrics is usually defined as the science that studies quantitatively the bibliographic material (Broadus 1987; Pritchard 1969). In the literature, it is very common to develop bibliometric studies of a wide range of issues including topics (Heradio et al. 2016; Moral-Muñoz et al. 2016; Liao et al. 2018a, b), journals (Biemans et al. 2007; Thongpapanl 2012), authors (Coupé 2003), universities (Cancino et al. 2017a; Linton 2004) and countries (Bonilla et al. 2015). Due to the strong development of computers, bibliometrics has become a very powerful technique for providing a general overview of a research field.

Note that there are also several bibliometric studies regarding different soft computing topics including fuzzy research (Cobo et al. 2011a, b; Merigó et al. 2015a), fuzzy and linguistic decision making (Blanco-Mesa et al. 2017; Liu and Liao 2017; Yu et al. 2016), intuitionistic fuzzy sets (Yu and Liao 2016; Yu and Shi 2015), ordered weighted averaging operators (Emrouznejad and Marra 2014; He et al. 2017), aggregation operators (Yu 2015) and computational intelligence (Van Eck and Waltman 2007). Recall that bibliometric studies represent an alternative approach to develop a literature review of a research field that can complement perfectly the classical review and survey papers. Observe that survey papers in soft computing research are available in a wide range of topics including intuitionistic fuzzy sets (Xu and Liao 2015), hesitant fuzzy sets (Liao et al. 2015, 2018b), group decision making (Capuano et al. 2018; Taibi and Atmani 2017), consensus analysis (Moral et al. 2018; Zhang et al. 2018) and applications in artificial intelligence such as big data and internet of things (Dhall and Solanki 2017; Settouti et al. 2016).

The study uses the Web of Science (WoS) Core Collection database. The search was carried out between November 2016 and January 2017 and finds all the documents in the journal since 2003. Note that for the documents published in the journal between 1997 and 2002, the work uses the "Cited Reference Search" tool of WoS, finding all the documents with at least one citation. For those papers that have not received any citation, the search finds them through the webpage of the journal. Up to 2016, the journal has published 2331 documents which decreases to 2037 if only considering articles, reviews and notes. It has received 17523 citations with a ratio of 7,52 cites per paper. The h-index is 48, that is, of the 2331 documents published in the journal, 48 have received 48 citations or more.

The analysis uses a wide range of bibliometric indicators (Merigó and Yang 2017) including the total number of publications and citations, the ratio cites per paper, the h-index (Alonso et al. 2009; Hirsch 2005; Martinez et al. 2014) and citations thresholds (Merigó et al. 2015a). The objective is to provide a general overview of the bibliographic material. The main reason for doing so is because there are different perspectives to consider when analyzing the bibliographic material. From a general point of view (Podsakoff et al. 2008), the two main perspectives are the number of publications that reflect the productivity and the number of citations that focus on the influence and popularity of a document.

Additionally, the work uses bibliographic coupling (Kessler 1963), co-authorship, co-occurrence, citation analysis and co-citation analysis (Small 1973) to develop the graphical analysis. Recall that co-citation occurs when two documents receive a citation from the same source and bibliographic coupling when two documents cite the same third work. Co-authorship appears when a document is written by more than one author. Citation analysis measures how different documents or sources cite each other. Co-occurrence of keywords measures the most common keywords in the set of documents. Observe that in this study co-occurrence focuses on

Table 1 Most productive authors in SC

R	Author name	Country	TP	TC	C/P	H	Q1	Q2	Q3	Q4
1	Pedrycz, W	Canada	27	97	3.59	5	1	12	3	11
2	Buckley, JJ	USA	18	252	14.00	9	0	12	6	0
3	Chajda, I	Czech Rep	18	61	3.39	4	0	0	5	13
4	Herrera, F	Spain	16	1023	63.94	11	0	3	9	4
5	Dvurecenskij, A	Slovakia	16	111	6.94	5	2	3	5	6
6	Allahviranloo, T	Iran	14	130	9.29	7	0	0	4	10
7	Wang, ST	China	13	93	7.15	5	0	7	3	3
8	Jiao, LC	China	13	26	2.00	2	0	0	0	13
9	Liu, ZQ	China	12	98	8.17	5	0	3	7	2
10	Alba, E	Spain	12	67	5.58	4	1	0	5	6
11	Zhang, MJ	China	12	33	2.75	3	0	0	2	10
12	Davvaz, B	Iran	10	355	35.50	7	0	3	5	2
13	Yager, RR	USA	10	173	17.30	3	3	0	5	2
14	Hong, TP	China	10	122	12.20	4	3	2	3	2
15	Chung, FL	China	10	40	4.00	4	0	5	3	2
16	Yang, SX	China	9	211	23.44	5	0	1	6	2
17	Yao, X	China	9	177	19.67	5	0	2	3	4
18	Melin, P	Mexico	9	116	12.89	4	0	1	3	5
19	Sanchez, L	Spain	8	469	58.63	5	1	1	5	1
20	Lozano, M	Spain	8	188	23.50	8	0	2	5	1
21	Castillo, O	Mexico	8	116	14.50	4	0	1	3	4
22	Ishibuchi, H	Japan	8	103	12.88	5	0	1	6	1
23	Li, YM	China	8	42	5.25	4	0	2	4	2
24	Pulmannova, S	Slovakia	8	6	0.75	1	0	1	4	3
25	Marcelloni, F	Italy	7	216	30.86	6	0	1	6	0
26	Lazzerini, B	Italy	7	216	30.86	6	0	1	6	0
27	Nojima, Y	Japan	7	116	16.57	5	0	1	6	0
28	Dudek, WA	Poland	7	100	14.29	5	0	0	6	1
29	Cheng, CH	Taiwan	7	88	12.57	5	0	5	2	0
30	Xu, Y	China	7	54	7.71	4	0	0	2	5
31	Shen, Q	China	7	28	4.00	3	0	0	3	4
32	Li, YY	China	7	25	3.57	2	0	1	0	6
33	Ventura, S	Spain	6	494	82.33	4	0	0	2	4
34	Eslami, E	Iran	6	155	25.83	5	0	3	2	1
35	Wang, XZ	China	6	77	12.83	4	0	0	4	2
36	Chen, CH	Taiwan	6	74	12.33	3	0	1	2	3
37	Abraham, A	India	6	71	11.83	4	0	0	4	2
38	Gao, JW	China	6	66	11.00	5	0	0	3	3
39	Kalra, PK	India	6	45	7.50	5	0	4	2	0
40	Lee, CS	Taiwan	6	45	7.50	4	0	0	2	4
41	Hirota, K	Japan	6	28	4.67	3	0	2	3	1
42	Jin, YC	China	6	10	1.67	2	0	0	0	6
43	Wang, YP	China	6	9	1.50	2	0	0	0	6
44	Vincekova, E	Slovakia	6	5	0.83	1	0	0	3	3
45	Saha, S	India	6	4	0.67	1	0	0	0	6
46	Das, S	India	5	81	16.20	3	0	0	2	3
47	Zhan, JM	China	5	49	9.80	4	0	0	4	1

Table 1 continued

R	Author name	Country	TP	TC	C/P	H	Q1	Q2	Q3	Q4
48	Zhou, LG	China	5	25	5.00	2	0	0	1	4
49	Zelinka, I	Czech Rep	5	21	4.20	3	0	0	0	5
50	Li, J	China	5	11	2.20	2	0	0	0	5

R = Rank; TP and TC = Total papers and citations; C/P = Cites per paper; H = *h*-index; Q1 = 1997–2001; Q2 = 2002–2006; Q3 = 2007–2011; Q4 = 2012–2016

Table 2 The most productive and influential institutions in SC

R	Institution	Country	TP	TC	H	C/P	≥ 50	≥ 25	≥ 5	ARWU	QS
1	U Granada	Spain	56	1628	18	29.07	3	4	13	201–300	501–550
2	Slovak Academy of Sciences	Slovakia	43	167	6	3.88	0	0	1	–	–
3	Islamic Azad U	Iran	42	375	11	8.93	0	1	4	–	–
4	Chinese Academy of Sciences	China	41	182	7	4.44	0	0	2	–	–
5	Palacky U Olomouc	Czech Rep	32	121	7	3.78	0	0	0	–	651–700
6	Xidian U	China	32	72	5	2.25	0	0	0	–	–
7	Indian Institute Tech	India	31	246	9	7.94	0	0	3	–	–
8	U Alberta	Canada	30	110	6	3.67	0	0	0	101–150	94
9	Czech Academy of Sciences	Czech Rep	24	382	8	15.92	1	1	5	–	–
10	U Salerno	Italy	23	134	6	5.83	0	0	1	401–500	–
11	City U Hong Kong	China	22	189	9	8.59	0	0	3	201–300	55
12	Hong Kong Polytechnic U	China	22	143	7	6.50	0	0	1	301–400	111
13	Jiangnan U	China	22	124	6	5.64	0	0	1	–	–
14	U Malaga	Spain	21	88	5	4.19	0	0	0	–	–
15	U Jaen	Spain	19	903	11	47.53	2	1	7	–	–
16	Tsinghua U	China	19	157	7	8.26	0	0	3	58	24
17	U Ostrava	Czech Rep	19	157	7	8.26	0	0	2	–	–
18	U Alabama Birmingham	USA	18	261	9	14.50	0	0	6	201–300	601–650
19	Slovak U Tech Bratislava	Slovakia	17	162	6	9.53	0	0	4	–	–
20	Polish Academy of Sciences	Poland	17	77	4	4.53	0	0	1	–	–
21	U Cordoba	Argentina	16	554	7	34.63	1	1	0	–	–
22	Hebei U	China	16	190	6	11.88	0	1	2	–	–
23	CNRS—France	France	16	184	7	11.50	0	1	1	–	–
24	Polytechnic U Madrid	Spain	16	113	5	7.06	0	0	0	–	551–600
25	U Oviedo	Spain	15	505	7	33.67	1	0	2	–	–
26	U Birmingham	UK	15	194	5	12.93	1	0	1	101–150	82
27	Shaanxi Normal U	China	15	69	6	4.60	0	0	0	–	–
28	Nanyang Tech U Singapore	Singapore	14	169	6	12.07	0	2	2	101–150	13
29	Shahid Bahonar U Kerman	Iran	14	156	5	11.14	0	1	2	–	–
30	National Cheng Kung U	China	14	91	4	6.50	0	1	0	401–500	241
31	Wuhan U	China	14	64	4	4.57	0	0	1	301–400	275
32	U Naples Federico II	Italy	14	51	5	3.64	0	0	0	301–400	481–490
33	Tongji U	China	14	43	4	3.07	0	0	0	301–400	315
34	National Chiao Tung U	China	13	107	6	8.23	0	0	1	401–500	174
35	Jadavpur U	India	13	96	3	7.38	0	0	2	–	–
36	Victoria U Wellington	New Zealand	13	33	3	2.54	0	0	0	301–400	228
37	King Abdulaziz U	Saudi Arabia	13	27	3	2.08	0	0	0	101–150	283
38	U Nottingham	UK	12	445	5	37.08	1	0	0	101–150	75

Table 2 continued

R	Institution	Country	TP	TC	H	C/P	≥ 50	≥ 25	≥ 5	ARWU	QS
39	Wroclaw U Tech	Poland	12	105	5	8.75	0	0	2	–	701
40	Southwest Jiaotong U	China	12	88	7	7.33	0	0	1	–	–
41	CSIC—Spain	Spain	12	85	5	7.08	0	0	0	–	–
42	Shanghai Jiao Tong U	China	12	82	4	6.83	0	0	1	101–150	61
43	Renmin U China	China	12	73	5	6.08	0	0	1	–	421–430
44	Nanjing U Science Tech	China	12	53	4	4.42	0	0	0	401–500	–
45	Tianjin U	China	12	30	3	2.50	0	0	0	301–400	481–490
46	Technical U Ostrava	Czech Rep	12	50	5	4.17	0	0	0	–	–
47	South China U Tech	China	12	44	3	3.67	0	0	0	201–300	551–600
48	U Yazd	Iran	11	371	8	33.73	1	1	3	–	–
49	Ulster U	UK	11	104	6	9.45	0	0	2	–	601–650
50	Sun Yat Sen U	China	11	39	4	3.55	0	0	0	151–200	297

Abbreviations are in Table 1 except for:≥ 50, ≥ 25, ≥ 5 = Number of documents with equal or more than 50, 25 and 5 citations and less than the previous threshold; ARWU and QS = Ranking of the university in the general ARWU and QS university rankings

the author keywords that usually appear below the abstract of an article.

In order to visualize and map the bibliographic material, the work uses VOS viewer (Van Eck and Waltman 2010). The difference between the software and the results of WoS Core Collection is that the software only focuses on the publications of the journal and the citations generated inside these documents. However, WoS Core Collection also considers the citations from documents published in other journals in order to measure the general impact this set of documents have in the scientific community (Blanco-Mesa et al. 2017). Note that in the literature there are many other softwares to develop a graphical analysis of the bibliographic material (Cobo et al. 2011a, b, 2012).

3 Results

This section presents the bibliometric results found in WoS Core Collection including the publication and citation structure, the citing articles, and the leading authors, universities and countries.

3.1 Leading authors, institutions and countries of SC

Many authors have published significant contributions in the journal since 1997. Table 1 presents a list with the fifty most productive authors until December 31, 2016. Note that several other indicators are considered including the number of citations, the *h*-index, the cites per paper ratio, citation thresholds and the number of publications divided in periods of 5 years.

Witold Pedrycz clearly obtains the first position with twenty-seven articles. However, in terms of citations and the *h*-index, Francisco Herrera obtains the most significant results far away from the rest of authors. Note that nineteen authors work at a Chinese institution, five in Spain, four in India and three in Iran, Japan, Slovakia and Taiwan.

Next, let us look into the leading institutions of the journal. For doing so, Table 2 presents the fifty most productive institutions.

The University of Granada clearly leads the ranking obtaining the most significant results in number of papers, citations and the *h*-index. Observe that eighteen institutions are from China, six from Spain and four from Czech Republic. Only one is from the USA.

In order to deepen the results of Table 2, let us look into the temporal evolution of the productivity. For doing so, Table 3 analyzes the annual number of publications of the thirty most productive institutions.

During the last 3 years, Chinese universities are emerging very strongly. Remark also that the University of Granada has not published many papers in the last years although between 2009 and 2013 it published thirty-eight papers.

A further interesting issue is to consider the country affiliation of the institutions in order to analyze the geographical regions with a highest productivity in SC. Table 4 presents the fifty most productive countries.

China clearly dominates the list with more than twice the number of papers of Spain, which is in the second place. The USA and the UK obtain the third and fourth positions, respectively. However, when normalizing per person, Czech Republic and Slovakia obtain the most remarkable results.

Next, let us analyze the publications by countries through a temporal evolution. For doing so, Table 5 presents the annual number of papers published by countries in SC. Note that those published before 2002 are summarized in a single

Table 3 Most productive institutions in SC throughout time

R	Universities	TP	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	Pre 2002	Q1	Q2	Q3	Q4
1	U Granada	50	0	1	1	9	7	10	7	5	2	3	0	1	0	1	3	0	0	5	27	18
2	Slovak Acad Sci	43	5	1	2	1	2	3	3	2	5	1	2	1	1	5	1	8	8	10	14	11
3	Islamic Azad U	42	4	7	4	5	9	7	3	1	1	0	1	0	0	0	0	0	0	1	12	29
4	Chinese Acad Sci	41	11	5	4	5	2	2	1	3	2	4	1	1	0	0	0	0	0	2	12	27
5	Xidian U	32	16	5	9	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	31
6	Palacky U Olomouc	32	3	5	4	3	5	5	1	2	0	1	2	0	0	1	0	0	0	3	9	20
7	Indian Inst Tech	31	6	3	2	5	2	2	2	0	1	1	2	1	1	1	1	1	1	6	6	18
8	U Alberta	30	3	2	4	2	0	1	0	0	2	2	2	3	2	2	4	1	1	13	5	11
9	Czech Acad Sci	24	0	2	0	0	1	0	0	0	2	1	1	4	2	5	1	5	5	13	3	3
10	U Salerno	23	2	1	1	1	3	0	2	0	0	0	1	4	1	0	2	5	5	8	2	8
11	City U Hong Kong	22	0	2	1	3	3	2	1	4	0	3	0	0	0	3	0	0	0	3	10	9
12	Hong Kong Polytec U	22	0	1	1	0	1	0	1	1	1	4	6	2	2	1	1	0	0	12	7	3
13	Jiangnan U	21	1	3	1	0	1	2	1	0	2	1	5	2	2	0	0	0	0	9	6	6
14	U Malaga	21	3	5	1	3	2	3	1	0	0	2	0	0	0	0	0	1	1	0	6	14
15	Tsinghua U	19	2	2	2	2	0	3	2	2	2	1	1	0	0	0	0	0	0	1	10	8
16	U Jaen	19	3	0	0	1	3	3	3	3	1	1	0	0	0	0	1	0	0	1	11	7
17	U Alabama Birmingham	19	0	0	0	0	0	0	0	1	3	2	1	4	3	1	3	1	1	12	6	0
18	U Ostrava	19	0	0	1	0	1	0	1	1	1	0	0	1	4	1	4	4	4	10	3	2
19	Slovak U Tech Bratislava	17	1	1	1	1	0	1	3	0	1	1	5	0	1	0	0	1	1	6	6	4
20	Polish Acad Sci	17	3	2	2	1	0	0	1	1	1	1	0	0	1	1	3	0	0	5	4	8
21	U Cordoba	16	1	0	1	2	4	1	2	1	2	0	1	1	0	0	0	0	0	2	6	8
22	Hebei U	16	0	1	0	3	3	1	1	1	0	6	0	0	0	0	0	0	0	0	9	7
23	CNRS—France	16	0	0	1	1	4	0	0	0	2	1	3	0	3	1	0	0	0	7	3	6
24	U Oviedo	15	3	0	0	0	3	3	2	2	1	0	1	0	0	0	0	0	0	1	8	6
25	Shaanxi Normal U	15	0	1	1	2	1	0	1	1	4	1	3	0	0	0	0	0	0	3	7	5
26	Wuhan U	14	3	6	1	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	11
27	Tongji U	14	4	4	0	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4	10
28	Shahid Bahonar U Kerman	14	1	1	0	1	2	3	0	0	2	1	1	0	1	1	0	0	0	3	6	5
29	National Cheng Kung U	14	2	2	3	2	0	2	0	1	1	0	1	0	0	0	0	0	0	1	4	9
30	Victoria U Wellington	13	4	3	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	11

Abbreviations are available in the previous tables. Note that each year indicates the number of papers published that year

Table 4 The most productive countries in SC

R	Country	TP	TC	H	C/P	Pop	TP/Pop	TC/Pop	≥ 100	≥ 50	≥ 20
1	China	546	2893	23	5.30	1371220	0.40	2.11	1	2	26
2	Spain	230	2793	23	12.14	46418.269	4.95	60.17	4	6	20
3	USA	197	1676	18	8.51	321418.82	0.61	5.21	2	5	14
4	UK	178	1587	16	8.92	65138.232	2.73	24.36	3	0	9
5	Iran	140	1177	17	8.41	79109.272	1.77	14.88	1	3	10
6	India	132	670	13	5.08	1311050.527	0.10	0.51	0	0	7
7	Taiwan	128	698	13	5.45	23113.99	5.54	30.20	0	1	5
8	Italy	127	972	14	7.65	60802.085	2.09	15.99	0	3	7
9	Czech Republic	107	724	13	6.77	10551.219	10.14	68.62	1	1	6
10	Japan	94	568	11	6.04	126958.472	0.74	4.47	0	0	8
11	Canada	77	421	11	5.47	35851.774	2.15	11.74	0	1	2
12	Germany	56	865	10	15.45	81413.145	0.69	10.62	1	2	6
13	Slovakia	54	291	9	5.39	5424.05	9.96	53.65	0	0	5
14	Turkey	53	369	10	6.96	78665.83	0.67	4.69	0	0	7
15	Australia	53	362	9	6.83	23781.169	2.23	15.22	0	0	3
16	France	52	421	12	8.10	66808.385	0.78	6.30	0	1	2
17	Poland	52	265	10	5.10	37999.494	1.37	6.97	0	0	3
18	Romania	51	336	8	6.59	19832.389	2.57	16.94	0	2	1
19	South Korea	49	183	7	3.73	50617.045	0.97	3.62	0	0	1
20	Greece	37	197	7	5.32	10823.732	3.42	18.20	0	0	2
21	Malaysia	32	256	6	8.00	30331.007	1.06	8.44	1	0	1
22	Austria	30	187	6	6.23	8611.088	3.48	21.72	0	0	6
23	Finland	29	725	12	25.00	5482.013	5.29	132.25	1	2	4
24	Singapore	29	273	7	9.41	5535.002	5.24	49.32	0	2	3
25	Mexico	26	176	6	6.77	127017.224	0.20	1.39	0	1	1
26	Belgium	25	502	8	20.08	11285.721	2.22	44.48	3	0	2
27	Saudi Arabia	21	41	3	1.95	31540.372	0.67	1.30	0	0	0
28	Portugal	19	105	6	5.53	10348.648	1.84	10.15	0	0	1
29	Brazil	17	226	5	13.29	207847.528	0.08	1.09	1	0	0
30	New Zealand	17	37	3	2.18	4595.7	3.70	8.05	0	0	0
31	Egypt	16	79	4	4.94	91508.084	0.17	0.86	0	0	1
32	Netherlands	16	54	5	3.38	16936.52	0.94	3.19	0	0	0
33	Argentina	13	196	3	15.08	43416.755	0.30	4.51	1	0	0
34	Sweden	10	79	4	7.90	9798.871	1.02	8.06	0	0	1
35	Tunisia	10	50	4	5.00	10982.754	0.91	4.55	0	0	0
36	Pakistan	9	186	3	20.67	188924.874	0.05	0.98	1	0	1
37	Hungary	9	165	3	18.33	9844.686	0.91	16.76	0	0	3
38	Switzerland	8	16	3	2.00	8286.976	0.97	1.93	0	0	0
39	Serbia	7	19	3	2.71	7098.247	0.99	2.68	0	0	0
40	South Africa	6	15	2	2.50	54956.92	0.11	0.27	0	0	0
41	Cyprus	5	64	4	12.80	1141.166	4.38	56.08	0	0	1
42	Jordan	5	27	3	5.40	7594.547	0.66	3.56	0	0	0
43	Ireland	5	19	3	3.80	4757.976	1.05	3.99	0	0	0
44	Cuba	5	17	2	3.40	11389.562	0.44	1.49	0	0	0
45	Slovenia	4	335	4	83.75	2063.768	1.94	162.32	1	1	0
46	Latvia	4	34	3	8.50	1978.44	2.02	17.19	0	0	1
47	Norway	4	15	2	3.75	5195.921	0.77	2.89	0	0	0

Table 4 continued

R	Country	TP	TC	H	C/P	Pop	TP/Pop	TC/Pop	≥ 100	≥ 50	≥ 20
48	Algeria	4	15	2	3.75	39666.519	0.10	0.38	0	0	0
49	Thailand	4	12	2	3.00	67959.359	0.06	0.18	0	0	0
50	Iraq	4	4	1	1.00	36423.395	0.11	0.11	0	0	0

Abbreviations are in Tables 1 and 2 except for: Pop = Population in thousands; TP/Pop, TC/Pop = Total publications and citations per million inhabitants

result. Additionally, the results are also shown in periods of 5 years.

During the first years of the journal, the USA and Italy were the most productive countries in the journal. However, since 2006, China has become the most productive country and today publishes about three times more than the second most productive country. From a general point of view, developing countries have been increasing their productivity in the journal although they still need to improve more in the future.

3.2 Publication and citation structure of SC

SC started publishing papers in 1997, and since then, it has grown significantly. Figure 1 shows the annual evolution of the number of papers published in the journal.

At the beginning, the journal was publishing about twenty to thirty papers. Since then, it started growing significantly surpassing the one hundred citation threshold in 2006. In 2015, SC published 261 documents and in 2016, 341.

Next, let us look into the general citation structure of the journal classified by years. Table 6 presents the results considering several citation thresholds and the impact factor.

Currently, there is a significant dispersion between the time the most cited papers were published. Note that papers published during the last 5 years still need more time to grow their number of citations. Observe that about 1.3% of the papers receive more than fifty citations, 5.8% more than twenty, and 61% receive at least one citation.

Focusing on the impact factor of the journal, SC is growing significantly the impact factor through time. Currently, SC obtains a remarkable result of 2.47 being on the second quartile of the journal ranking of the Journal Citation Reports (2016 edition) of the Web of Science category of Computer Science, Artificial Intelligence. The last column of Table 6 shows how SC is getting better positions in the journal ranking of Computer Science and Artificial Intelligence, through time. Note that due to the recent expansion in the number of journals indexed in the Web of Science Core Collection through the Emerging Sources Citation Index, SC has very good chances to improve its ranking becoming a quartile 1 journal in the near future.

Another interesting issue to consider is those variables that cite more the journal. For doing so, Table 7 shows the journals, authors, universities and countries that have cited more SC. Note that the table considers the citing articles. Nevertheless, inside each article there may be one or more citations to the journal.

The self-citations of SC are the most remarkable one which is very common in most of the journals. Information Sciences, Applied Soft Computing and Fuzzy Sets and Systems show a strong connection with SC. Francisco Herrera is the most significant author, and the University of Granada is the institution that cites more the journal. Spain reaches the second place, which is very remarkable considering his size. The first position goes to China that strongly leads the ranking showing the strong influence SC is having in Asia.

In order to identify more specifically the most cited papers of the journal until now, Table 8 presents a list with the fifty most cited. Note that these results are up to the beginning of 2017 when all the publications of 2016 were available. However, these data are dynamic so the rankings may change in the future.

The most cited paper was published by Jesús Alcalá-Fernández, Luciano Sánchez, Salvador García and other co-authors (Alcalá-Fernández et al. 2009). This work presented software for assessing evolutionary algorithms for data mining problems. Both the second and the third most cited papers focus on evolutionary computation.

Another interesting issue to analyze is to identify those papers that are most cited in the documents published in the journal. To assess this issue, let us use VOS viewer software in a co-citation analysis of documents. Table 9 presents the results.

The most cited paper in the journal is the seminal paper of Lotfi A. Zadeh about fuzzy sets. Note that this paper is the most cited paper in computer science of all the time and among the fifty most cited papers of all the time of all sciences (Merigó et al. 2015a). Five books are among the ten most cited documents in the journal and eleven in the top 30. Note that the references of the table only include the first author of each document. The total link strength indicates the connections with other documents that have at least received twenty citations in the journal.

Table 5 Temporal evolution of the publications classified by countries

R	Country	TP	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	Pre 2002	Q1	Q2	Q3	Q4
1	China	546	129	96	60	50	34	50	22	26	19	24	21	3	3	5	1	3	3	33	141	369
2	Spain	224	30	16	14	24	31	30	20	11	12	8	6	10	0	2	6	4	4	24	81	115
3	USA	197	17	10	7	16	5	13	6	6	18	12	12	13	15	5	16	26	26	61	55	55
4	UK	178	22	24	10	27	8	20	3	10	2	4	8	6	4	7	7	16	16	32	39	91
5	Iran	140	25	25	14	11	20	14	5	5	10	4	5	0	1	1	0	0	0	7	38	95
6	India	132	38	20	15	10	5	10	7	3	4	4	6	3	1	3	1	2	2	14	28	88
7	Taiwan	128	14	15	14	9	12	8	5	7	7	10	9	3	3	0	3	9	9	18	37	64
8	Italy	127	9	7	7	6	7	7	7	3	6	3	7	14	4	3	6	31	31	34	26	36
9	Czech Republic	107	9	7	14	8	8	7	3	3	3	2	5	5	6	11	4	12	12	31	18	46
10	Japan	94	7	2	3	3	2	6	9	6	6	12	5	5	4	5	8	11	11	27	39	17
11	Canada	77	12	6	8	6	2	5	0	2	7	5	5	6	3	2	5	3	3	21	19	34
12	Slovakia	68	6	2	3	2	3	4	6	2	6	3	8	1	2	5	1	14	14	17	21	16
13	Germany	56	3	3	1	7	2	1	0	1	2	7	5	7	2	2	6	7	7	22	11	16
14	Turkey	53	10	9	5	4	4	3	4	5	3	1	3	1	0	1	0	0	0	5	16	32
15	Australia	53	8	1	2	2	4	8	2	3	2	7	3	1	2	3	2	3	3	11	22	17
16	Poland	52	10	9	6	4	0	1	3	2	7	1	2	0	1	1	3	2	2	7	14	29
17	France	52	3	1	4	1	7	2	2	1	5	4	8	0	6	4	1	3	3	19	14	16
18	Romania	51	7	1	6	0	6	6	2	2	1	3	0	4	3	3	0	7	7	10	14	20
19	South Korea	49	8	9	8	1	8	0	2	3	3	4	0	0	0	1	2	0	0	3	12	34
20	Greece	37	1	2	1	2	5	1	1	2	1	0	1	10	2	1	2	5	5	16	5	11
21	Malaysia	32	9	9	1	1	0	3	0	1	1	1	5	0	1	0	0	0	0	6	6	20
22	Austria	30	2	3	2	3	2	4	0	0	0	2	0	1	3	2	2	4	4	8	6	12
23	Finland	29	0	1	2	3	2	4	3	1	3	0	0	3	3	0	3	1	1	9	11	8
24	Singapore	29	4	4	1	3	1	1	1	1	1	3	3	0	0	1	3	2	2	7	7	13
25	Mexico	26	5	5	3	2	2	2	1	0	0	1	2	1	0	0	0	2	2	3	4	17
26	Belgium	24	1	0	2	2	0	1	4	0	1	3	1	2	1	2	0	4	4	6	9	5
27	Saudi Arabia	21	9	6	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	20
28	Portugal	19	2	2	2	1	2	3	0	0	1	2	0	4	0	0	0	0	0	4	6	9
29	Brazil	17	0	4	1	3	0	5	0	1	0	0	2	0	0	1	0	0	0	3	6	8
30	Egypt	16	4	4	0	2	0	0	2	2	1	0	0	1	0	0	0	0	0	1	5	10

Abbreviations are available in the previous tables

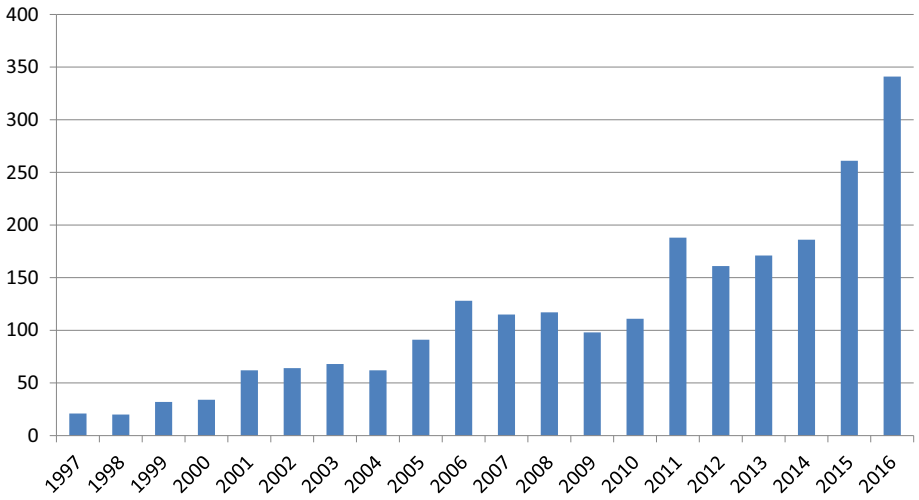

Fig. 1 Annual number of publications in SC

Table 6 Annual citation structure of SC

Year	TP	TC	H	≥ 100	≥ 50	≥ 20	≥ 10	≥ 5	≥ 1	IF	IF (%)
1997	21	598	10	2	1	4	3	3	8	–	–
1998	20	314	8	1	0	3	3	4	6	–	–
1999	32	388	11	1	0	3	8	3	9	–	–
2000	34	386	9	1	0	2	5	3	11	–	–
2001	62	373	10	0	1	1	7	12	16	–	–
2002	64	757	17	0	3	9	12	8	20	–	–
2003	68	697	13	1	1	5	10	14	20	–	–
2004	62	525	13	0	2	6	7	15	20	0.33	16.67
2005	91	1587	18	3	0	14	11	15	26	0.53	26.46
2006	128	1533	20	1	6	12	20	27	37	0.51	22.10
2007	115	1401	19	2	4	11	19	21	34	0.60	31.90
2008	117	1261	20	0	2	15	27	18	35	0.98	37.76
2009	98	1860	20	2	4	13	27	14	21	1.32	54.17
2010	111	1245	18	2	2	11	15	29	35	1.51	57.59
2011	188	1669	20	0	4	16	31	34	59	1.88	74.84
2012	161	976	15	0	1	5	20	35	62	1.12	41.57
2013	171	869	13	0	0	5	16	31	79	1.30	47.15
2014	186	522	10	0	0	0	7	20	82	1.27	45.59
2015	261	381	8	0	0	1	3	11	62	1.63	56.29
2016	341	181	4	0	0	1	0	1	28	2.47	67.41
Total	2331	17523	48	16	31	137	251	318	670	–	–
%	100	–	–	0.69	1.33	5.88	10.77	13.64	28.74	–	–

Abbreviations are available in Tables 1 and 2 except for IF = Impact factor of the Journal Citation Reports 2016; IF% = Percentile ranking in the WoS category (Computer Science, Artificial Intelligence) according to the IF (the results are between 0 and 100, being 0 the last position in the ranking and 100 the first position)

4 Graphical analysis of SC with VOS viewer software

VOS viewer software collects the bibliographic material providing general maps by using several bibliometric indicators including bibliographic coupling, co-citation, co-authorship, citation analysis and co-occurrence of keywords (Van Eck and Waltman 2010). In order to provide a different perspective from the results of the previous section, this chapter develops a graphical visualization of the publications of SC. By doing so, the reader obtains a more general representation of the results being able to see the results from two different points of view.

Table 7 Citing articles of SC

R	Journal name	TP	Author	TP	University	TP	Country	TP
1	Soft Computing	699	Herrera, F	129	U Granada	300	China	2409
2	Information Sciences	443	Davvaz, B	81	Islamic Azad U	182	Spain	925
3	Applied Soft Computing	307	Zhan, JM	75	U Jaen	137	Iran	660
4	Fuzzy Sets and Syst	266	Pedrycz, W	52	King Abdulaziz U	104	USA	549
5	J Intelligent Fuzzy Syst	232	Herrera-Viedma, E	43	Chinese Acad Sci	104	UK	485
6	Expert Syst with Applications	227	Chen, XH	42	Nanyang TechU Singapore	90	India	459
7	Neurocomputing	154	Mesiar, R	38	Palacky U Olomouc	87	Taiwan	381
8	Knowledge Based Syst	150	Jun, YB	37	CNRS—France	85	Italy	327
9	IEEE Trans Fuzzy Syst	125	Dvurecenskij, A	37	Cordoba U	84	Czech Rep	274
10	Neural Computing Applications	115	Ventura, S	35	U Yazd	82	Turkey	257
11	Mathematical Problems in Engin	102	Merigo, JM	35	Indian Inst Tech	80	Canada	223
12	IEEE Trans Evolutionary Comput	92	Garcia, S	33	Central South U	80	France	214
13	Int J Approximate Reasoning	90	Fernandez, A	33	Slovak Acad Sci	79	Australia	201
14	Int J Computational Intell Syst	78	De Baets, B	31	Xidian U	69	S. Korea	183
15	Int J Uncert Fuzz Knowl Based Syst	66	Yang, SX	30	Huazhong U Science Tech	67	Poland	166
16	Iranian J Fuzzy Syst	63	Xu, ZS	27	Shahid Bahonar U Kerman	66	Malaysia	161
17	Int J Intelligent Syst	63	Del Jesus, MJ	27	Polish Acad Sciences	65	Japan	161
18	Eur J Operational Research	62	Chajda, I	26	Northeastern U China	64	S. Arabia	153
19	Engineering Applic Artificial Intell	61	Bustince, H	26	Ghent U	63	Romania	148
20	Computers Mathematics Applic	58	Shabir, M	25	Tsinghua U	62	Slovakia	144
21	J Multiple Valued Logic Soft Comp	55	Saeid, AB	24	Tongji U	61	Germany	139
22	Scientific World J	54	Cordon, O	24	Amirkabir U Technology	61	Singapore	125
23	Applied Mathematics Computation	48	Yin, YQ	23	Slovak U Tech Bratislava	60	Greece	105
24	IEEE Trans Cybernetics	41	Wang, JQ	23	U Tehran	59	Pakistan	104
25	Swarm and Evolutionary Comput	41	Suganthan, PN	23	Hong Kong Polytechnic U	59	Mexico	101
26	Applied Intelligence	40	Ma, XL	23	Czech Acad Sciences	59	Belgium	97
27	Computers Industrial Engineering	38	Xu, YJ	22	U Alberta	58	Brazil	93
28	Int J Machine Learning Cybernetics	37	Wang, ST	22	Sichuan U	58	Austria	74
29	Int J Fuzzy Syst	36	Leoreanu-Fotea, V	22	Eur Ctr Soft Comp	57	Finland	67
30	Int J Advanced Manufacturing Tech	36	Jiao, LC	22	Xi An Jiaotong U	56	Portugal	54

Abbreviations are available in Table 1

Table 8 The 50 most cited documents in SC according to WoS Core Collection

R	TC	Title	Author/s	Year	C/Y
1	395	KEEL: A software tool to assess evolutionary algorithms for data mining problems	Alcala-Fdez, J; Sanchez, L; Garcia, S; et al.	2009	56.43
2	346	A comprehensive survey of fitness approximation in evolutionary computation	Jin, Y	2005	31.45
3	323	A fuzzy adaptive differential evolution algorithm	Liu, J; Lampinen, J	2005	29.36
4	218	A study of statistical techniques and performance measures for genetics-based machine learning: accuracy and interpretability	Garcia, S; Fernandez, A; Luengo, J; Herrera, F	2009	31.14
5	185	Artificial immune systems as a novel soft computing paradigm	de Castro, LN; Timmis, JI	2003	14.23
6	180	Basic fuzzy logic is the logic of continuous t-norms and their residual	Cignoli, R; Esteva, F; Godo, L; Torrens, A	2000	11.25
7	156	Soft sets combined with fuzzy sets and rough sets: a tentative approach	Feng, F; Li, CX; Davvaz, B; Ali, MI	2010	26.00
8	153	Exploring dynamic self-adaptive populations in differential evolution	Teo, J	2006	15.30
9	148	The uses of fuzzy logic in autonomous robot navigation	Saffiotti, A	1997	7.79
10	121	Experimental study on population-based incremental learning algorithms for dynamic optimization problems	Yang, SX; Yao, X	2005	11.00
11	121	Basic fuzzy logic and BL-algebras	Hajek, P	1998	6.72
12	115	Centered OWA operators	Yager, RR	2007	12.78
13	113	Soft computing: the convergence of emerging reasoning technologies	Bonissone, PP	1997	5.95
14	111	Analyzing consensus approaches in fuzzy group decision making: advantages and drawbacks	Cabrerizo, FJ; Moreno, JM; Perez, IJ; Herrera-Viedma, E	2010	18.50
15	104	Performance comparison of self-adaptive and adaptive differential evolution algorithms	Brest, J; Boskovic, B; Greiner, S; Zumer, V; Maucec, MS	2007	11.56
16	101	Residual operators of uninorms	De Baets, B; Fodor, J	1999	5.94
17	96	Operator and parameter adaptation in genetic algorithms	Smith, J.E.; Fogarty, TC	1997	5.05
18	94	Multilayer feedforward neural network based on multi-valued neurons (MLMVN) and a backpropagation learning algorithm	Aizenberg, I; Moraga, C	2007	10.44
19	93	(epsilon epsilon v q)-fuzzy subnear-rings and ideals	Davvaz, B	2006	9.30
20	86	Super-fit control adaptation in memetic differential evolution frameworks	Caponio, A; Neri, F; Tirronen, V	2009	12.29
21	83	Pseudo-t-norms and pseudo-BL algebras	Flondor, P; Georgescu, G; Iorgulescu, A	2001	5.53
22	81	DE/BBO: a hybrid differential evolution with biogeography-based optimization for global numerical optimization	Gong, WY; Cai, ZH; Ling, CX	2011	16.20
23	78	Adaptation and application of multi-objective evolutionary algorithms for rule reduction and parameter tuning of fuzzy rule-based systems	Gacto, MJ; Alcala, R; Herrera, F	2009	11.14
24	78	Diversity-adaptive parallel memetic algorithm for solving large scale combinatorial optimization problems	Tang, J; Lim, MH; Ong, YS	2007	8.67
25	75	JCLEC: a Java framework for evolutionary computation	Ventura, S; Romero, C; Zafra, A; Delgado, JA; Hervás, C	2008	9.38
26	72	Gradual elements in a fuzzy set	Dubois, D; Prade, H	2008	9.00

Table 8 continued

R	TC	Title	Author/s	Year	C/Y
27	69	Evolutionary rule-based systems for imbalanced data sets	Orriols-Puig, A; Bernado-Mansilla, E	2009	9.86
28	69	Some types of filters in BL algebras	Haveshki, M; Saeid, AB; Eslami, E	2006	6.90
29	68	Optimization in dynamic environments: a survey on problems, methods and measures	Cruz, C; Gonzalez, JR; Pelta, DA	2011	13.60
30	66	Memetic algorithm using multi-surrogates for computationally expensive optimization problems	Zhou, ZZ; Ong, YS; Lim, MH; Lee, BS	2007	7.33
31	64	Bosbach states on fuzzy structures	Georgescu, G	2004	5.33
32	60	Fuzzy relation equations (I): the general and specialized solving algorithms	Chen, L; Wang, PP	2002	4.29
33	60	Dynamic ensemble extreme learning machine based on sample entropy	Zhai, JH; Xu, HY; Wang, XZ	2012	15.00
34	57	Self-adaptive differential evolution algorithm using population size reduction and three strategies	Brest, J; Maucec, MS	2011	11.40
35	57	Scale factor inheritance mechanism in distributed differential evolution	Weber, M; Tirronen, V; Neri, F	2010	9.50
36	57	Context adaptation of fuzzy systems through a multi-objective evolutionary approach based on a novel interpretability index	Botta, A; Lazzerini, B; Marcelloni, F; Stefanescu, DC	2009	8.14
37	56	A Pareto-based multi-objective evolutionary approach to the identification of Mamdani fuzzy systems	Cococcioni, M; Ducange, P; Lazzerini, B; Marcelloni, F	2007	6.22
38	55	A communication model based on the 2-tuple fuzzy linguistic representation for a distributed intelligent agent system on internet	Delgado, M; Herrera, F; Herrera-Viedma, F; Martín-Bautista, MJ; Martinez, L; Vila, MA.	2002	3.93
39	54	Optimization of interval type-2 fuzzy logic controllers using evolutionary algorithms	Castillo, O; Melin, P; Alanis, A; Montiel, O; Sepulveda, R	2011	10.80
40	53	A GA-based fuzzy mining approach to achieve a trade-off between number of rules and suitability of membership functions	Hong, TP; Chen, CH; Wu, YL; Lee, YC	2006	5.30
41	53	Artificial neural networks and genetic algorithm for bearing fault detection	Samanta, B; Al-Balushi, KR; Al-Araimi, SA	2006	5.30
42	52	Hybrid learning models to get the interpretability-accuracy trade-off in fuzzy modeling	Alcala, R; Alcala-Fdez, J; Casillas, J; Cordón, O; Herrera, F	2006	5.20
43	52	Edge detection using ant algorithms	Nezamabadi-pour, H; Saryazdi, S; Rashedi, E	2006	5.20
44	52	Observations on non-commutative fuzzy logic	Hajek, P	2003	4.00
45	52	An algorithmic description of XCS	Butz,M.V.; Wilson SW	2002	3.71
46	50	Multi-objective self-adaptive differential evolution with elitist archive and crowding entropy-based diversity measure	Wang, YN; Wu, LH; Yuan, XF	2010	8.33
47	50	Uncertain probabilities II: the continuous case	Buckley, JJ; Eslami, E	2004	4.17
48	48	Self-adaptive differential evolution with multi-trajectory search for large-scale optimization	Zhao, SZ; Suganthan, PN; Das, S	2011	9.60
49	48	Tabu search for attribute reduction in rough set theory	Hedar, AR; Wang, J; Fukushima, M	2008	6.00
50	48	Faster convergence by means of fitness estimation	Branke, J; Schmidt, C	2005	4.36

Abbreviations are available in Table 1 except for: C/Y = Citations per year

First, let us consider co-citation of journals. Recall that it occurs when two documents from different journals receive a citation from the same third document of another journal (Small 1973). The graph visualizes the most cited journals, and the network connections indicate those journals that are more co-cited. Figure 2 shows the results considering a threshold of fifty citations and the one hundred most representative co-citation connections.

Table 9 Most cited documents in SC publications

R	Year	Cited reference	Type	Citations	TLS
1	1965	Zadeh LA, Inform Control, vol 8, p 338	A	203	137
2	1989	Goldberg DE, Genetic Algorithms	B	124	90
3	1995	Kennedy J, IEEE Int Conf Neural Networks Proc, vols 1-6, p 1942	C	98	81
4	2002	Deb K, IEEE T Evolut Comput, vol 6, p 182	A	92	74
5	1997	Storn R, J Global Optim, vol 11, p 341	A	82	73
6	1975	Zadeh LA, Inform Sciences, vol 8, p 199	A	78	65
7	1981	Bezdek JC, Pattern Recognition	B	62	37
8	1998	Hajek P, Metamathematics of Fuzzy Logic	B	55	40
9	1975	Holland JH, Adaptation in Natural and Artificial Systems	B	55	45
10	2001	Deb K, Multiobjective Optimization	B	52	50
11	2000	Dvurecenskij A, New Trends in Quantum Structures	B	50	43
12	1992	Koza JR, Genetic Programming	B	45	24
13	2009	Garcia S, J Heuristics, vol 15, p 617	A	44	41
14	1999	Zitzler E, IEEE T Evolut Comput, vol 3, p 257	A	41	38
15	1993	Quinlan JR, C4.5: Programs for Machine Learning	B	39	28
16	2006	Demsar J, J Mach Learn Res, vol 7, p 1	A	38	34
17	1985	Takagi T, IEEE T Syst Man Cyb, vol 15, p 116	A	38	28
18	1998	Vapnik VN, Statistical Learning Theory	B	38	17
19	1986	Atanassov KT, Fuzzy Set Syst, vol 20, p 87	A	37	32
20	1982	Pawlak Z, Int J Comput Inf Sci, vol 11, p 341	A	37	23
21	1999	Yao X, IEEE T Evolut Comput, vol 3, p 82	A	37	35
22	2009	Qin AK, IEEE T Evolut Comput, vol 13, p 398	A	36	36
23	2000	Cignoli R, Algebraic Foundations of Many-Valued Reasoning	B	34	29
24	2006	Brest J, IEEE T Evolut Comput, vol 10, p 646	A	33	32
25	2009	Garcia S, Soft Comput, vol 13, p 959	A	33	31
26	2001	Georgescu G, Multiple Valued Logic, vol 6, p 95	A	33	33
27	1997	Wolpert DH, IEEE T Evolut Comput, vol 1, p 67	A	33	32
28	1988	Yager RR, IEEE T Syst Man Cyb, vol 18, p 183	A	33	17
29	2007	Zhang QF, IEEE T Evolut Comput, vol 11, p 712	A	32	30
30	1995	Vapnik VN, The Nature of Statistical Learning Theory	B	31	18

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

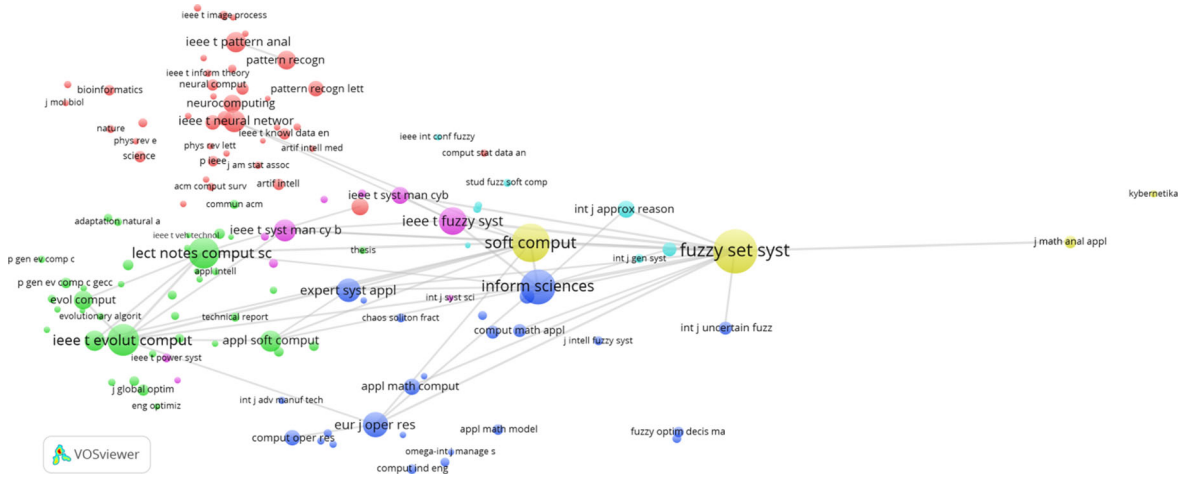

Fig. 2 Co-citation of journals cited in SC

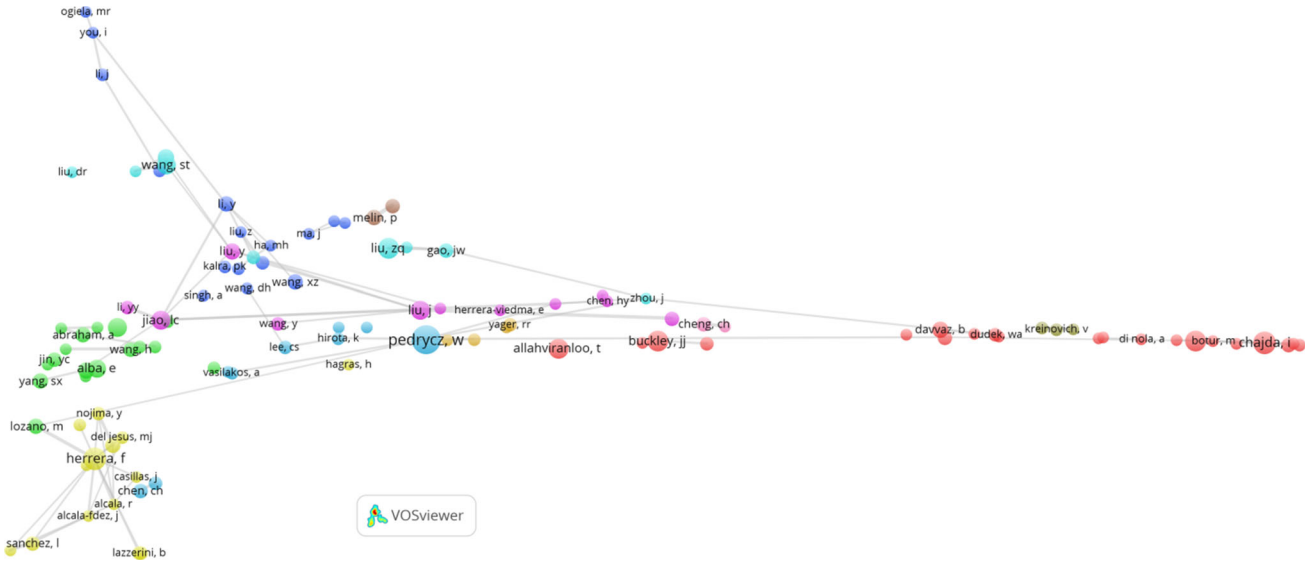

Fig. 3 Bibliographic coupling of authors that publish in SC

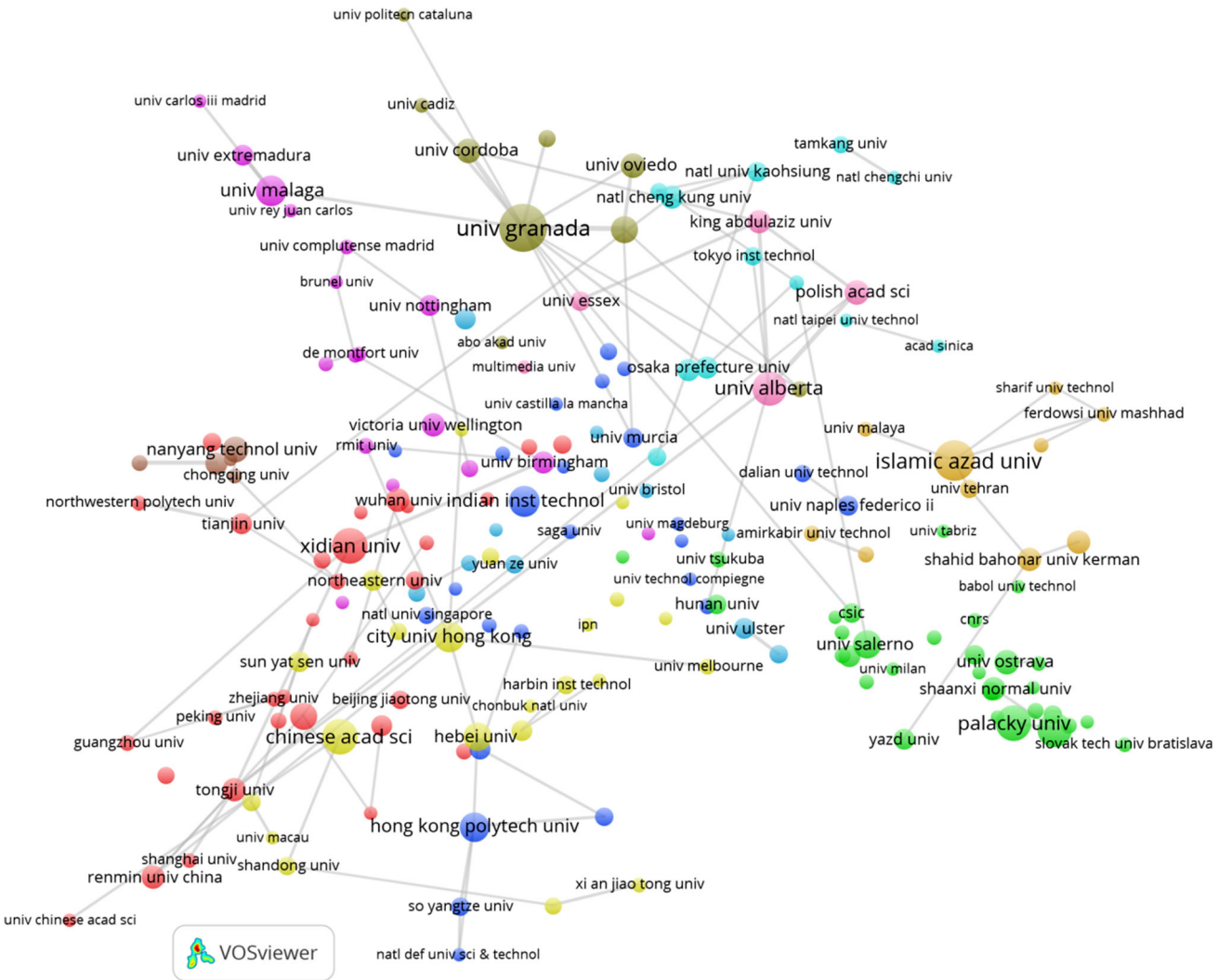

Fig. 4 Bibliographic coupling of institutions that publish in SC

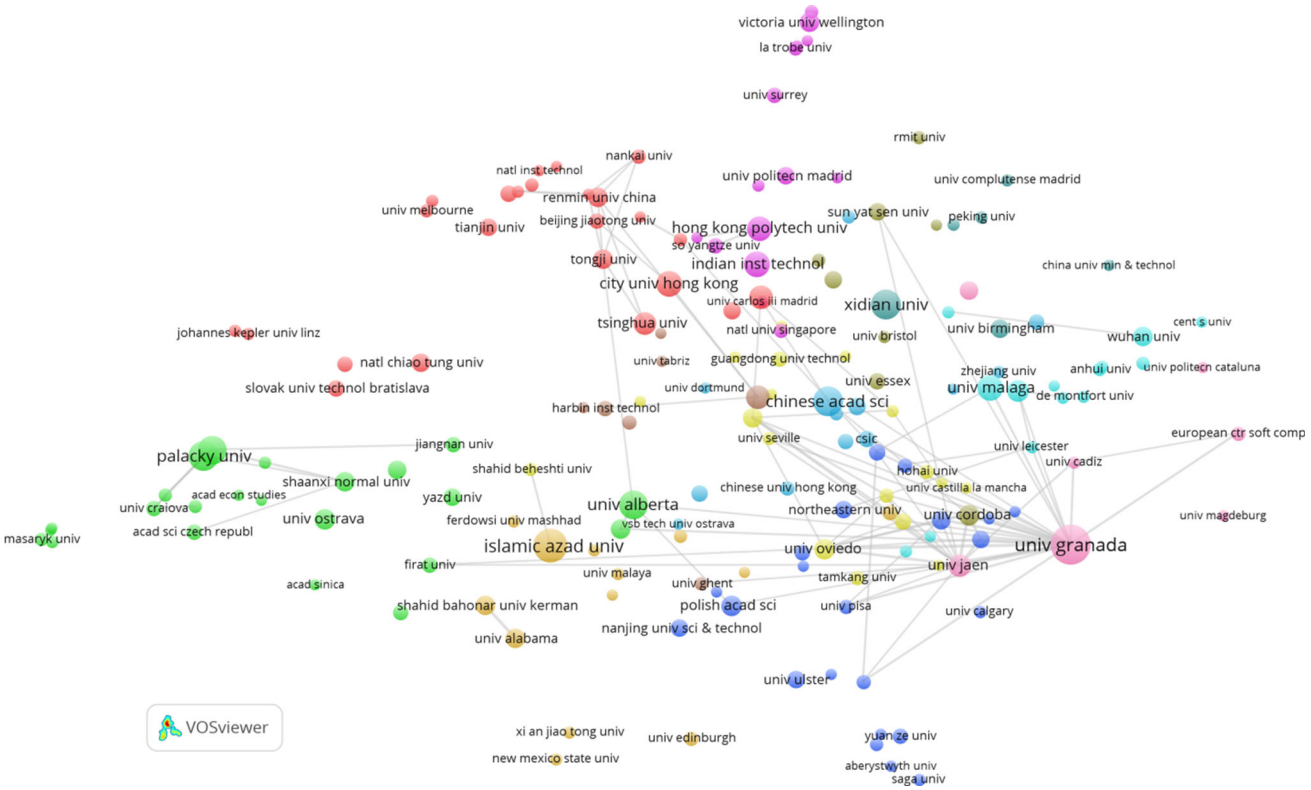

Fig. 5 Citation analysis of institutions publishing in SC

Fuzzy Sets and Systems is the most cited journal in SC followed by Information Sciences and SC itself. The journals that form the core strongly connect to the field of computer science with a strong focus on the emerging theories of soft computing and related issues. It is also worth noting that the Lecture Notes in Computer Science has a strong influence in the journal.

Next, let us analyze bibliographic coupling of authors that publish in SC. Bibliographic coupling (Kessler 1963) of authors analyzes the authors of two documents that cite the same third document. Thus, in the map appears the name of the authors of these documents. Particularly, the graph presents the most productive authors when dealing with all the set of documents. In addition, the network connections show those authors that cite the same bibliographic material with the aim of identifying authors with similar research profiles. Figure 3 visualizes the results considering a threshold of five documents published in the journal and the one hundred most representative bibliographic coupling connections.

Witold Pedrycz and Francisco Herrera form the most representative cores. In general, the results are quite consistent with the results of Table 1. The main advantage of Figure 3 is that it visualizes those authors with similar profiles either because they work on similar topics or because they are co-authors.

Bibliographic coupling can also be studied from the institutional perspective. Here, the difference is that the map visualizes the most productive institutions in terms of the institutional affiliation of the authors that publish in SC. The network connections represent the authors of institutions that cite many times the same bibliographic references showing similar research profiles. Figure 4 shows the results with a threshold of five documents published in the journal and the one hundred most significant bibliographic coupling connections.

The University of Granada is the most productive institution and represents one of the key cores of the journal. The results of this figure are in accordance with the results of Table 2 although in the figure the universities appear according to their research profile connections with other institutions.

Another interesting issue to consider is how the institutions cite each other. For doing so, the work develops a citation analysis of institutions that publish in SC. Note that the size of the circles shows the most productive institutions as in Fig. 4. However, the network connections visualize the institutions that cite each other significantly. Observe that the network connections sum the citations from institution *A* to institution *B* and the citations from institution *B* to institution *A*. Figure 5 presents the results visualizing those institutions

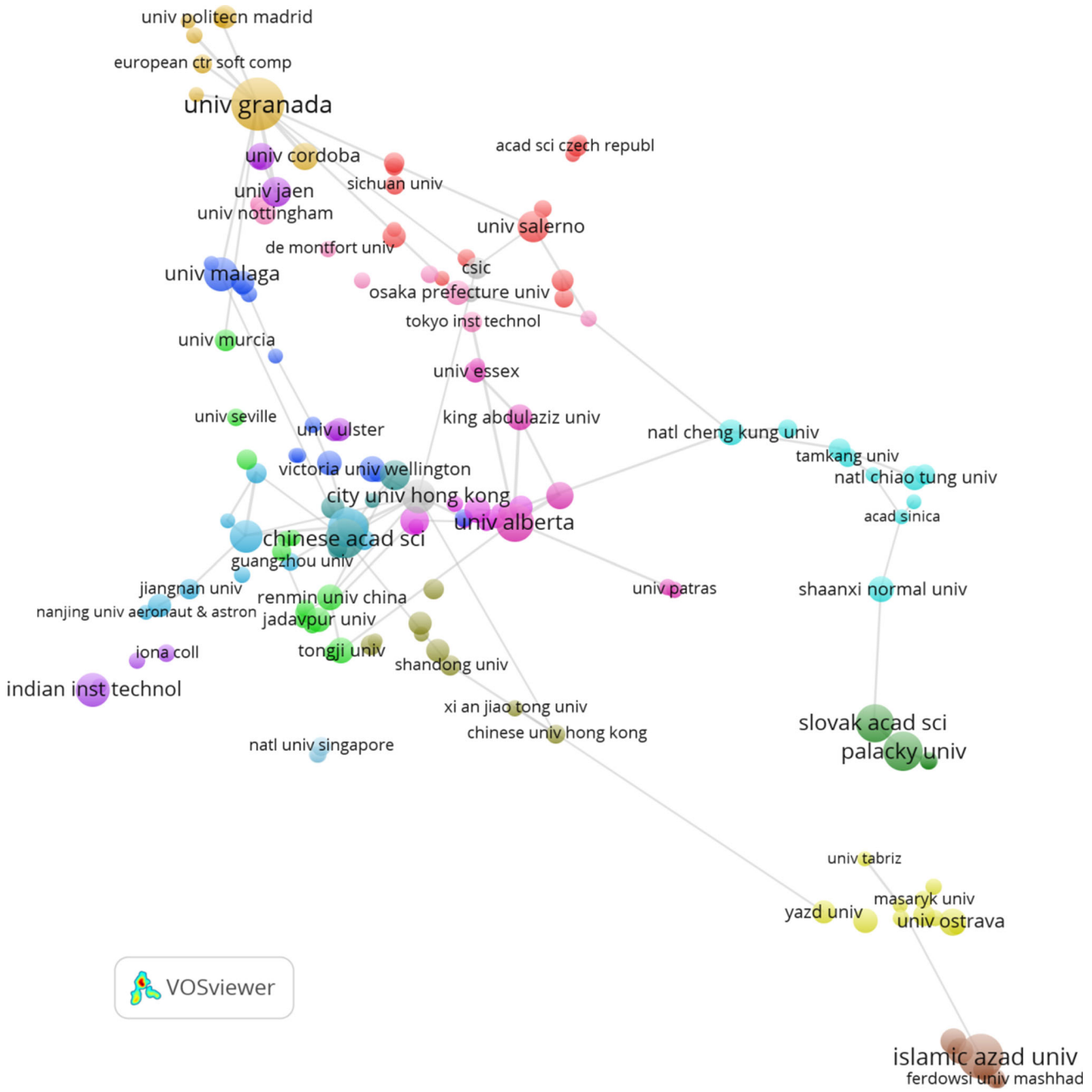

Fig. 6 Co-authorship of institutions that publish in SC

with at least five documents published in SC and the one hundred most representative citation links.

The University of Granada obtains the most remarkable results due to its strong productivity that generates many outgoing and incoming citations. It is worth noting that it is very common that universities from the same country or region tend to connect strongly. Note that some authors that work at an institution are foreigners making the institutions to connect with other unexpected institutions. A representative example is the case of Witold Pedrycz that works at the University of Alberta but has strong connections with the Polish Academy of Sciences. Therefore, both institutions appear strongly connected in the figure.

Additionally, it is also interesting to visualize co-authorship between universities in order to identify the main co-authoring institutions of the journal. Figure 6 shows the results considering a threshold of five documents and one hundred co-authorship connections.

In terms of productivity, the same institutions as in Figures 4 and 5 appear here. Moreover, here it is very clear the

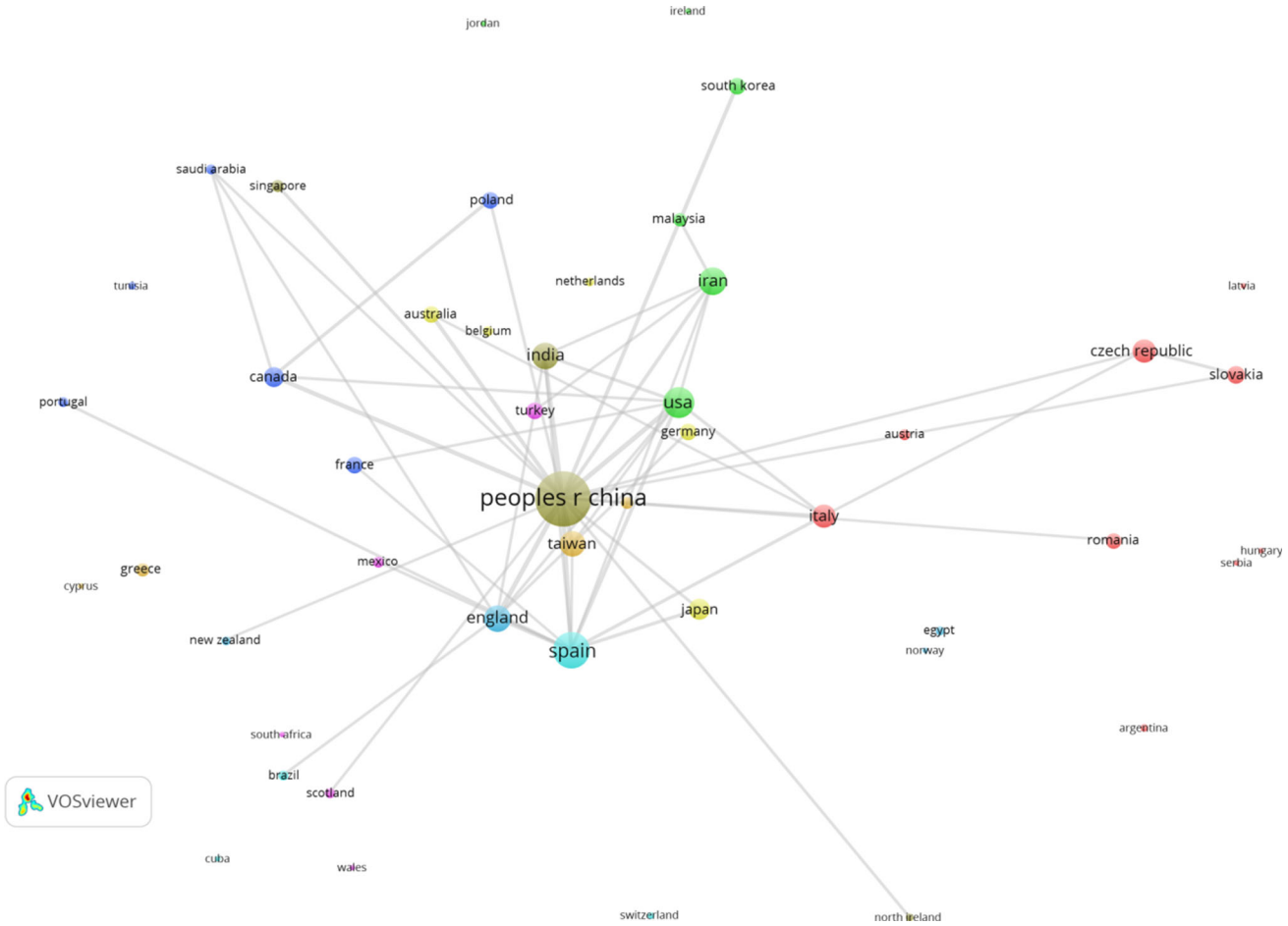

Fig. 7 Bibliographic coupling of countries that publish in SC

local co-authoring connections where institutions from the same country or region tend to collaborate more than with institutions from other countries. Figure 6 strongly visualizes this for the case of Spain and China.

Next, let us map the results at the country level (Merigó et al. 2016). Here, the graph shows the countries of the institutions shown previously. Implicitly this includes the authors that work at these institutions independently of their nationality. Figure 7 presents bibliographic coupling of countries with a threshold of five documents and one hundred connections.

China is the most productive country and therefore represents the main core of the journal followed by Spain, USA, India and the UK. Note that the results of the UK come from the publications of England, Scotland, Wales and Northern Ireland. Observe that countries with a huge population tend to obtain better results in absolute numbers. Although not shown in the graph, recall the results of Table 4 in order to see the output normalized in terms of results per person.

Finally, let us focus on the most common keywords used in the journal in order to identify the leading topics that SC is publishing. For doing so, the study considers the author keywords that usually appear below the abstract. The map shows those keywords with the highest occurrence inside the set of documents of SC and the network connections indicate the keywords that tend to appear frequently in the same documents. Figure 8 presents the results considering a threshold of five occurrences and the one hundred most representative co-occurrence links.

Genetic and evolutionary algorithms are the most common keywords that appear in the journal. Some other popular topics are particle swam optimization, neural networks and fuzzy logic. Note that since soft computing is a trivial keyword, it does not appear so much in the documents published in the journal. Figure 8 clearly shows that today evolutionary computation has been the leading topic in the journal. On the other hand, the other main parts of soft computing, such as neural networks and fuzzy logic, have a significant position in the journal although currently their publication volume is well below that of evolutionary computation.

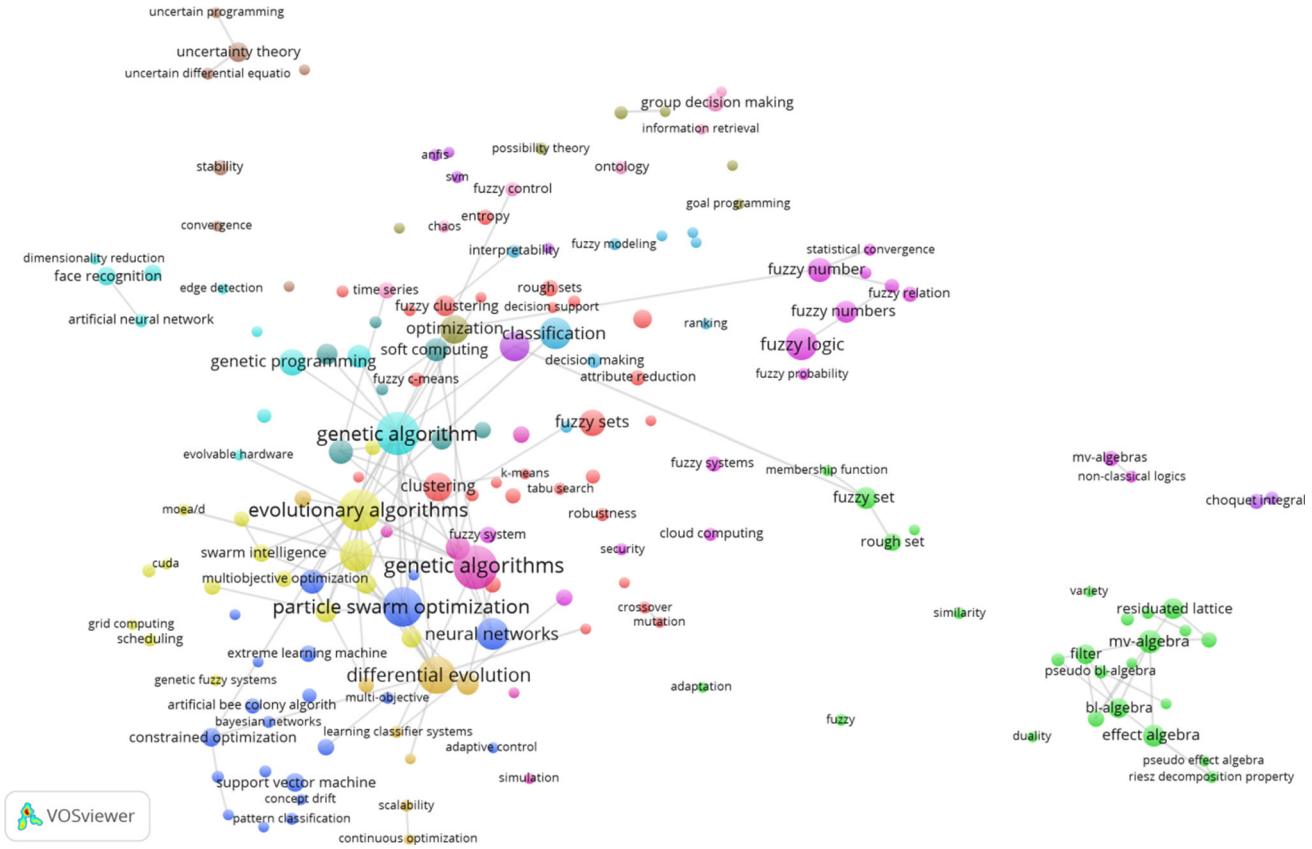

Fig. 8 Co-occurrence of author keywords of documents published in SC

5 Conclusions

Motivated by the twentieth anniversary of the journal, this study presents a bibliometric overview of the publications of the journal between 1997 and 2016. The results show a strong increase in the journal becoming a monthly journal since 2005. Today, the journal publishes more than three hundred documents every year and is recognized as one of the leading journals in the field of computer science. The study uses several bibliometric indicators to identify the leading trends occurring in the journal.

The University of Granada (Spain) is the most influential institution in the journal although China is the most productive country. However, if the numbers are normalized per capita, then the Spanish institutions achieve a more remarkable result. In terms of authors, Witold Pedrycz is the most productive author in the journal, while Francisco Herrera is the most influential one.

Mapping analysis is very useful to provide a general view of the publication and citation structure of the documents published and cited in SC. This work uses VOS viewer software. The main reason for using two different perspectives is to see two different representations and compare the results and their differences. The VOS viewer software provides a deeper visualization of the publication and citation structure of the key variables of the journal. The network connections show which authors, journals and/or institutions connect between them in terms of bibliographic coupling and co-citation. It is worth noting that soft computing includes three huge fields: evolutionary computation, neural network theory and fuzzy systems. Currently, the journal seems to publish more on topics focused on evolutionary computation rather than the other two areas. However, this may change in the future depending on the importance that each subarea may achieve under the scope of the journal.

Future research could expand the analysis considering additional bibliometric issues in the study including a deeper temporal evolution of the publications and more results with other graphical software such as Science Mapping Analysis Tool (SciMAT) (Cobo et al. 2011a, b, 2012). Note that other journals shall be considered in order to provide a better view of the publications in this field of study and also other topics.

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Compliance with ethical standards

Conflict of interest The authors declare that they do not have any conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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