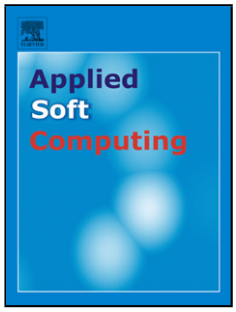

Title: Applied Soft Computing: A Bibliometric Analysis of the Publications and Citations during (2004-2016)

Authors: Pranab K. Muhuri, Amit K. Shukla, Manvendra Janmaijaya, Aparna Basu

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Applied Soft Computing: A Bibliometric Analysis of the Publications and Citations during (2004-2016)

Pranab K. Muhuri Amit K. Shukla Manvendra Janmaijaya Aparna Basu
Department of Computer Science
South Asian University, Akbar Bhavan, Chanakyapuri, New Delhi-110021, Indian

Highlights

- Bibliometric analysis of ASOC publications (2004-2016) with Web of Science (WoS) data.
- Main influencing aspects that govern the ASOC publications are highlighted.
- The distribution of citations over the years, citing sources and an aerial view of the citation structure is also given.
- ASOC authorship is analyzed, the author co-citation network is also given.
- Country-wise temporal and quantitative analysis of the ASOC publications are given.

ABSTRACT

The Journal of Applied Soft Computing (ASOC) is a highly reputed journal in the field of engineering and computer science. This study reviews the ASOC publications during the period 2004-2016 which are indexed in the Web of Science (WoS). The motive behind this study is to reveal the main influencing aspects that govern the ASOC publications and its citation structure using scientometric methods. The citation structure of the journal is analyzed first, which includes the distribution of citations over the years, citing sources and an aerial view of the citation structure. Then, the ASOC authorship is analyzed and the author co-citation network displayed. Further, a country-wise temporal and quantitative analysis of the publications is given along with the highly cited documents among the ASOC publications. Document co-citation analysis is also performed to reveal the intellectual base of ASOC publications.

Keywords: ***Applied Soft Computing; Bibliometric study; Scientometric mapping; Co-citation analysis; Web of Science.***

1. INTRODUCTION

Soft computing is a sub category of computational techniques concerned with approximate solutions to computationally intractable tasks, like problems that can be classified as Nondeterministic Polynomial (NP) hard which do not yield deterministic solutions in polynomial time [1]. Soft computing in its present form came after a degree of influence from fuzzy sets [2], complex systems and decision processes [3] and possibility theory and soft data analysis [4] etc. Later, evolutionary computing [5] and neural computing [6] were also added to it. Applied Soft Computing (ASOC) is one of the prominent international journals in the domain of soft computing research and applications. It is published by Elsevier Press. The scope of the journal covers soft computing techniques such as Fuzzy Logic, Neural Networks, Evolutionary Computing, Rough Sets and other similar techniques that address complex real-world problems [7].

Bibliometrics (also called Scientometrics) involves statistical analysis of written publications such as books or scientific articles. Typically, bibliographic data from citation indexes (viz., titles, abstracts, journal, author name, author addresses etc.) are statistically analyzed to determine the popularity and impact of specific articles, authors and institutions, or entire fields. Results are used in policy planning or performance evaluation, as well as to draw up a historiography of authors, journals, subject fields, institutions or countries. While individual and institutional output are required for performance evaluation and planning, country output can indicate strategic development of R&D in different countries. Scientometrics is widely used to support decision making and science policy today due to the vast increase in scientific research, and the near impossibility of evaluation that would require experts in many fields who could read and evaluate the literature. Scientometrics therefore gives an aerial view of scientific activity.

Several studies in the scientometrics of fuzzy sets and related soft computing areas have already been done. Studies on specific research areas are by Yu (2015) on aggregation operator research [8], Fuzzy decision making (2017) by Blanco-Mesa et al. [12], Ordered weighted averaging operators (2014) by Emrouznejad [14], Atanassov intuitionistic fuzzy sets (2015) by Yu and Shi [18], Fuzzy research (2015) by Merigo et al. [16], Linguistic decision making studies (2016) by Yu et al. [17], Real-time operating systems (2018) by Shukla et al. [81], and fuzzy theory research in China (2018) by Yu et al. [84]. In addition some studies have looked at the development of journals in this research area. Cobo et al. (2015) studied 25 years of the journal Knowledge Based Systems (KBS) [13], Merigo et al. (2016) studied the first thirty years of the International Journal of Intelligent Systems (IJIS) [15], Xu et al. (2017) have examined the structure and citation landscape of IEEE Transactions on Fuzzy Systems (TFS) [9], Laengle et al. (2017) looked at 40 years of the European Journal of Operations Research (EJOR) [11], and Cancino et al. (2017) studied the thirty years of Computers & Industrial Engineering [82]. Yu et al. (2017) studied the publications of the Information Sciences (INS) 1968-2016 [10], which was later extended by Merigó et al. (2018) with a bibliometric overview of its fifty years of publications in [83].

The main aim of this paper is to create a bibliometric profile of the journal ASOC including its growth over the last 12 years (2004-2016), identify the most frequently published authors, the main subject areas covered, the institutions to which the authors were affiliated and the countries where they were located. The bibliometric analysis of a single journal creates a general picture of the journal and depicts the quality and productivity of the journal in a particular field, and this study can further include the contribution of a country, institute or author. Collaborations and co-

occurrence of terms are explored through visualizations. A list of the most highly cited articles is also provided. In essence the paper tries to provide a historiography of the development of ASOC and the highlights.

The paper is organized as follows: Section 2 describes the data source and the methodology used for this study. Section 3 shows the publications and citation structure of ASOC. Section 4 depicts the authorship and institution analysis of the publications. Section 5 shows the country wise analysis of ASOC publications. In Section 6, we have included the document co-citation analysis. The overall discussion and a concise conclusion is drawn in Section 7.

2. DATA COLLECTION AND METHODOLOGY

The data for this study is collected for a period of 12 years (2004-2016) from the Science Citation Index-Expanded and Social Science Citation Index of the Web of Science. The SCI is the first multidisciplinary bibliographic index of journal publications designed, and currently covers over 12,000 journals. It is considered a standard data source for bibliometrics. Other databases such as Scopus by Elsevier are also used by bibliometricians. The data was collected in April, 2017. A total of 3680 publications were retrieved for the above said period. The query used in the search engine of WoS was "SO = Applied Soft Computing". Each record of the data retrieved from WoS comprises of a number of fields such as author, author affiliation, title, abstract, citations record etc.

The approach used here includes the use of typical scientometric characterizations along with certain statistical analysis. Three types of relationships between papers have been explored, viz., co-citation, co-authorship and bibliometric coupling. Co-citation analysis is another way to analyze the citation structure and provides a glimpse of the relationships between papers, and through them other entities, inside a research domain. It basically tells us that if two entities are co-cited, i.e., cited together more frequently then there are closer academic or disciplinary ties between them. Bibliographic coupling is the opposite of co-citation, it is the number of times two entities cite the same entity. Both co-citation and bibliographic coupling indicate disciplinary links. The number of co-authored documents identifies collaborative or co-authorship links between two entities, directly linking authors, institutions or countries. (By entity we mean either an author, an organization, or a country.)

For analysis, the variables used are Total Papers (TP) - the total number of papers from a particular source, Total Citations (TC) - the total number of citations generated by a particular publication, Citations per Paper (CPP) - TP divided by TC, and the Hirsch index or h-index which is equal to the number of papers (N) of an entity that has more than N citations each [19].

Graphical Mapping Software: i) VOSviewer and ii) CiteSpace

i) The bibliographic coupling and co-authorship between different entities is shown with the help of graphs (Figs. 3-5) For visualization we have used VOSviewer which is a tool for creating and visualizing bibliographic networks [20]. VOSviewer can be used to construct networks of scientific publications, scientific journals, researchers, research organizations, countries, keywords, or terms. Items in these networks can be connected by co-authorship, co-occurrence, citation, bibliographic coupling, or co-citation links. Examples are bibliographic coupling links between publications, co-authorship links between researchers, and co-occurrence links between terms. The strength of a link may for example indicate the

number of cited references two publications have in common (in the case of bibliographic coupling links), the number of publications two researchers have co-authored (in the case of co-authorship links), or the number of publications in which two terms occur together (in the case of co-occurrence links). Items may be grouped into clusters. A cluster is a set of items included in a cohesive group. In the visualization of a map, items with a higher weight are shown more prominently than items with a lower weight. Items are represented by their label and by default also by a circle. The size of the label and the circle of an item is determined by the weight of the item. The higher the weight of an item, the larger the label and the circle of the item. For some items the label may not be displayed, to avoid overlapping. The color of an item is determined by the cluster to which the item belongs. Lines between items represent links. Bibliographic data can be used to construct a network of co-authorship, co-occurrence, citation, bibliographic coupling, or co-citation, which are then displayed as a mapping.

ii) Citescape [21] has also been used here for visualization of the bibliographic coupling between ASOC publications. It is an open source Java application used for visualizing trends from metadata of scientific literature. It helps in understanding and analysis of network patterns.

3. PUBLICATION AND CITATION STRUCTURE OF ASOC

The first volume of ASOC came in the year 2001. The journal was included in the Web of Science indexing from the year 2004 with 43 published papers followed by 32 papers in 2005, 24 papers in 2006 and since then the total number of publications never came below 100. Fig. 1 shows the number of publications in ASOC from 2004 to 2016. However, ASOC sees a sudden increase in publication in year 2011 with 548 papers as compared to 123 papers in the previous year. The overall publication trend seems to be uneven over the years. The year 2015 shows the highest number of publications with 654 papers with top research areas being Genetic Algorithms (GAs), Particle Swarm Optimization (PSO) and Multi-Objective Optimization (MOO). The aforesaid topics were also among the top research areas in the last five years. The average number of publication is 306 per year.

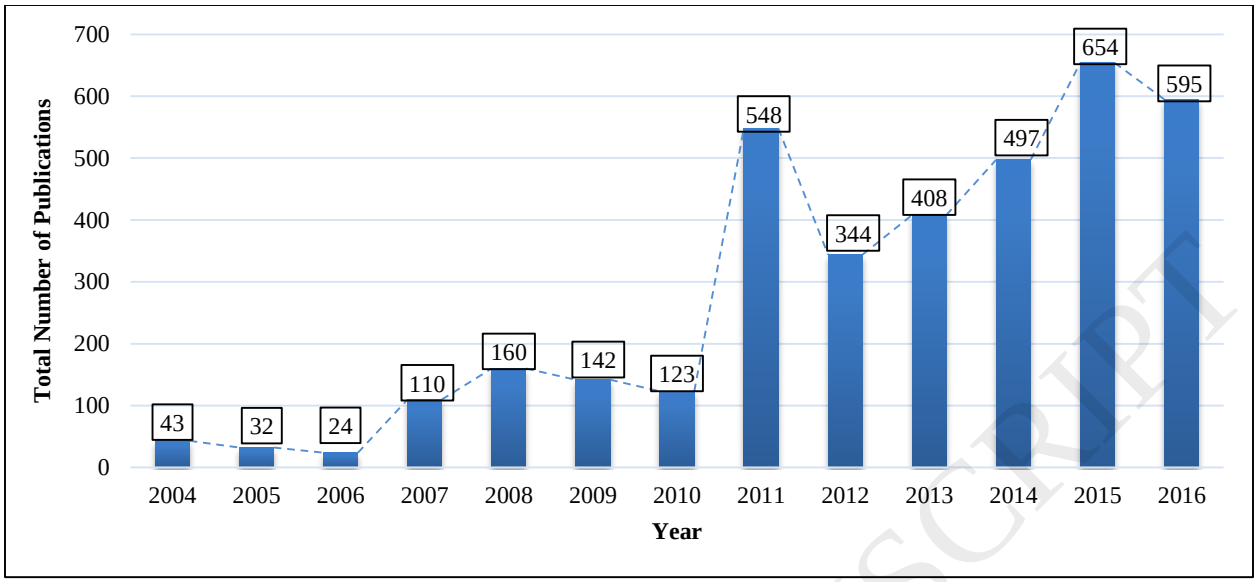

Fig. 1: Total number of ASOC publications by years (2004-2016)

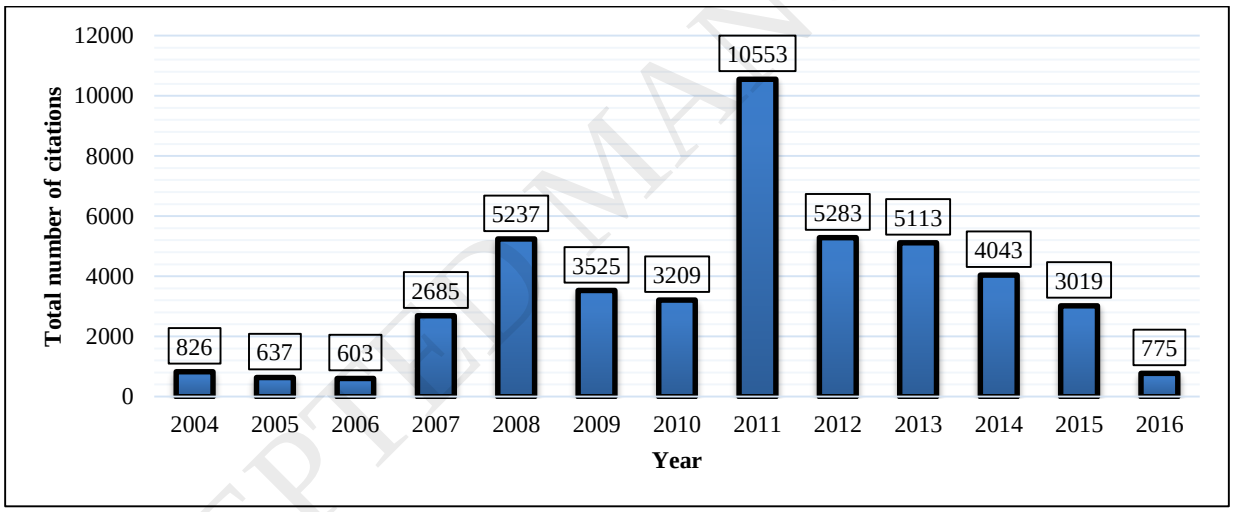

Fig. 2: Total citations by year (2004-2016)

The distribution of year wise citation counts over the time span of 12 years from 2004 to 2016 is shown in Fig. 2. The highest total citations were received by ASOC papers published in 2011. However, the highest *citations per paper* - (33) were received by papers published in 2008. Among the total publications, papers by Mallipeddi et al. [22] and Karaboga et al. [23] were cited the most number of times with 350 and 302 citations, respectively. The average citation per paper was 13. In the period between 2008 and 2016 the citations fetched by the journal were averaged at around 4528 per year.

Table 1 shows that only 0.11% of the ASOC publications received more than 200 citations, 0.98% more than 100 citations, 3.51 % more than 50 citations 15.92 % received more than 20 citations, 34.35 % received more than 10 citations and more than half of ASOC publications i.e. 54.16% received more than 5 citations. The four papers with more than 200 citations were

published between 2008-2011 by Karaboga and Basturk [23], Mallipeddi et al. [22], Karaboga and Ozturk [24] and Wei [25]. Of the total ASOC publications, 14.95% received no citations at all. It is clear from Table 1 that most of these papers came from 2016, and did not have enough time to obtain citations. Table 1 also presents year-wise values of TP, TC, CPP and h-index of ASOC.

Table 1: General citation Structure in the Journal: Applied Soft Computing (2004-2016)

Year	≥ 200	≥ 100	≥ 50	≥ 20	≥ 10	≥ 5	≥ 1	0	h-index	TP	TC	CPP
2016	0	0	0	0	1	24	247	348	18	595	775	1
2015	0	0	0	12	59	191	536	118	15	654	3019	5
2014	0	0	2	34	123	269	468	29	12	497	4043	8
2013	0	0	11	63	169	296	395	13	30	408	5113	13
2012	0	4	11	75	181	264	333	11	38	344	5283	15
2011	2	11	36	143	308	414	531	17	31	548	10553	19
2010	1	4	14	50	83	102	122	1	30	123	3209	26
2009	0	7	15	54	91	114	140	2	44	142	3525	25
2008	1	6	21	70	103	136	156	4	34	160	5237	33
2007	0	2	13	48	79	100	106	4	32	110	2685	24
2006	0	1	3	10	15	19	23	1	27	24	603	25
2005	0	0	2	10	23	28	31	1	19	32	637	20
2004	0	1	1	17	29	36	42	1	8	43	826	19
Total	4	36	129	586	1264	1993	3130	550	-	3680	45508	-
Percentage	0.11	0.98	3.51	15.92	34.35	54.16	85.05	14.95	100.00			

Table 2 lists the top 25 journals, institutions and countries/territories that have published documents citing ASOC publications. From the table, it can be seen that ASOC is on the top of the Journal source list with 2078 citations. The Expert Systems with Applications, Information Sciences, Mathematical Problems in Engineering, Neurocomputing and Journal of Intelligent Fuzzy Systems have frequently cited ASOC with, 933, 645, 481, 457 and 432 citations, respectively. They are followed by Knowledge Based Systems (344), Soft Computing (333), International Journal of Electrical Power and Energy Systems (280), International Journal of Advanced Manufacturing Technology (251), Engineering Applications of Artificial Intelligence (229) and Neural Computing Applications (222).

Among the institutions, the Islamic Azad University at Tehran in Iran is the leading institute in terms of the number of documents citing ASOC publications with 783 papers. The Indian Institute of Technology (IIT) from India with 470 papers and Chinese Academy of Sciences from China with 343 papers are in the second and third spots, respectively. If the top 10 list is considered, then the list has 4 institutions from Iran, 3 from China and 2 from Malaysia and 1 from India.

Among the countries/territories, Peoples Republic of China had 7194 papers citing ASOC, followed by Iran with 2677 papers and India with 2386 papers. United States of America (1584),

Taiwan (1569), Spain (1304), Turkey (1177) and England (876) have also cited the journal ASOC quite frequently.

Table 2: Journals, Institutions and Countries citing Applied Soft Computing (2004-2016)

Rank	Journals		Institutions		Country	
	Source	Total Papers	Source	Total Papers	Source	Total Papers
1	Applied Soft Computing	2078	Islamic Azad University, Iran	783	Peoples R China	7194
2	Expert Systems with Applications	933	Indian Institute of Technology IIT, India	470	Iran	2677
3	Information Sciences	645	Chinese Academy of Sciences, China	343	India	2386
4	Mathematical Problems in Engineering	481	University of Tehran, Iran	332	USA	1584
5	Neurocomputing	457	Amirkabir University of Technology, Iran	283	Taiwan	1569
6	Journal of Intelligent Fuzzy Systems	432	Iran University Science Technology, Iran	266	Spain	1304
7	Knowledge Based Systems	344	Huazhong University of Science Technology, China	264	Turkey	1177
8	Soft Computing	333	Dalian University of Technology, China	247	England	876
9	International Journal of Electrical Power Energy Systems	280	Universiti Malaya, Malaysia	241	Malaysia	861
10	International Journal of Advanced Manufacturing Technology	257	Universiti Teknologi, Malaysia	231	Canada	674
11	Computers Industrial Engineering	251	University of Granada, Spain	210	Australia	655
12	Engineering Applications of Artificial Intelligence	229	National Taiwan University of Science Technology, Taiwan	190	South Korea	515
13	Neural Computing Applications	222	Beihang University, China	180	Italy	453
14	International Journal of Production Research	165	Central South University, China	178	Brazil	447
15	Applied Mathematical Modelling	145	Hong Kong Polytechnic University, China	178	France	443
16	Scientific World Journal	137	Northeastern University, China	176	Saudi Arabia	360
17	IEEE Transactions on Fuzzy Systems	135	Nanyang Technological University, Singapore	170	Poland	359
18	International Journal of Computational Intelligence Systems	134	Nanyang Technological University National Institute of Education NIE, Singapore	170	Mexico	335
19	Applied Mathematics and Computation	126	Shanghai Jiao Tong University, China	168	Japan	299
20	Energy	126	Xidian University, China	161	Greece	259
21	European Journal of Operational Research	124	Zhejiang University, China	161	Singapore	257
22	Computers Operations Research	122	Xi An Jiaotong University, China	159	Germany	247
23	Applied Intelligence	118	Harbin Institute of Technology, China	158	Pakistan	219
24	Energy Conversion and Management	117	Sichuan University, China	150	Serbia	190
25	Sensors	114	Southeast University China, China	150	Portugal	185

Table 3: Top 40 Most Cited papers in Applied Soft Computing (2004-2016)

Rank	Title	Year	Author(s)	TC	Citations/year
1	On the performance of artificial bee colony (ABC) algorithm [23]	2008	Karaboga D; Basturk, B	1073	134.13
2	Differential evolution algorithm with ensemble of parameters and mutation strategies [22]	2011	Mallipeddi R; Suganthan, P. N; Pan, Q. K; Tasgetiren, M. F	350	70.00

3	A novel clustering approach: Artificial Bee Colony (ABC) algorithm [24]	2011	Karaboga Dervis; Ozturk, Celal	302	60.40
4	Some induced geometric aggregation operators with intuitionistic fuzzy information and their application to group decision making [25]	2010	Wei Guiwu	277	46.17
5	Cuckoo Optimization Algorithm [26]	2011	Rajabioun Ramin	183	36.60
6	An artificial bee colony algorithm for the leaf-constrained minimum spanning tree problem [27]	2009	Singh Alok	179	25.57
7	A new chaos-based fast image encryption algorithm [28]	2011	Wang Yong; Wong, Kwok-Wo; Liao, Xiaofeng; Chen, Guanrong	172	34.40
8	Firefly Algorithm for solving non-convex economic dispatch problems with valve loading effect [29]	2012	Yang Xin-She; Hosseini, Seyyed Soheil Sadat; Gandomi, Amir Hossein	170	42.50
9	A modified Artificial Bee Colony (ABC) algorithm for constrained optimization problems [30]	2011	Karaboga Dervis; Akay, Bahriye	170	34.00
10	A hybrid genetic algorithm and particle swarm optimization for multimodal functions [31]	2008	Kao Yi-Tung; Zahara, Erwie	166	20.75
11	Hybrid metaheuristics in combinatorial optimization: A survey [32]	2011	Blum Christian; Puchinger, Jakob; Raidl, Guenther R; Roli, Andrea	156	31.20
12	A novel particle swarm optimization algorithm with adaptive inertia weight [33]	2011	Nickabadi Ahmad; Ebadzadeh, Mohammad Mehdi; Safabakhsh, Reza	152	30.40
13	Fuzzy hierarchical TOPSIS for supplier selection [34]	2009	Wang Jia-Wen; Cheng, Ching-Hsue; Kun-Cheng, Huang	152	21.71
14	Application areas of AIS: The past, the present and the future [35]	2008	Hart Emma; Timmis, Jon	151	18.88
15	Hybrid neural network models for hydrologic time series forecasting [36]	2007	Jain Ashu; Kumar, Avadhnam Madhav	148	16.44
16	The use of computational intelligence in intrusion detection systems: A review [37]	2010	Wu Shelly Xiaonan; Banzhaf, Wolfgang	142	23.67
17	Evaluation of services using a fuzzy analytic hierarchy process [38]	2004	Mikhailov L; Tsvetinov, P	133	11.08
18	A distributed PSO-SVM hybrid system with feature selection and parameter optimization [39]	2008	Huang Cheng-Lung; Dun, Jian-Fan	131	16.38
19	A review on the design and optimization of interval type-2 fuzzy controllers [40]	2012	Castillo Oscar; Melin, Patricia	128	32.00
20	Hybridizing particle swarm optimization with differential evolution for constrained numerical and engineering optimization [41]	2010	Liu Hui; Cai, Zixing; Wang, Yong	128	21.33
21	A genetic algorithms based multi-objective neural net applied to noisy blast furnace data [42]	2007	Pettersson F; Chakraborti, N; Saxen, H	127	14.11
22	Recent Advances in Artificial Immune Systems: Models and Applications [43]	2011	Dasgupta Dipankar; Yu, Senhua; Nino, Fernando	125	25.00
23	The best-so-far selection in Artificial Bee Colony algorithm [44]	2011	Banharnsakun Anan; Achalakul, Tiranee; Sirinaovakul, Booncharoen	122	24.40
24	A comparative analysis of training methods for artificial neural network rainfall-runoff models [45]	2006	Srinivasulu S; Jain, A	115	11.50
25	An efficient hybrid approach based on PSO, ACO and k-means for cluster analysis [46]	2010	Niknam Taher; Amiri, Babak	114	19.00
26	Artificial Bee Colony (ABC) for multi-objective design optimization of composite structures [47]	2011	Omkar S. N; Senthilnath, J; Khandelwal, Rahul; Naik, G. Narayana; Gopalakrishnan, S	113	22.60
27	Influence of crossover on the behavior of Differential Evolution Algorithms [48]	2009	Zaharie Daniela	113	16.14
28	Particle swarm optimization with adaptive population size and its application [49]	2009	Chen DeBao; Zhao ChunXia	109	15.57
29	Comparison of particle swarm optimization and genetic algorithm for FACTS-based controller design [50]	2008	Panda Sidhartha; Padhy, Narayana Prasad	108	13.50
30	Dimensionality reduction based on rough set theory: A review [51]	2009	Thangavel K; Pethalakshmi, A	106	15.14
31	Extension of fuzzy TOPSIS method based on interval-valued fuzzy sets [52]	2009	Ashtiani Behzad; Haghighirad, Farzad; Makui, Ahmad; Montazer, Golam Ali	104	14.86
32	Closeness coefficient based nonlinear programming method for interval-valued intuitionistic fuzzy multiattribute decision making with incomplete preference information [53]	2011	Li Deng-Feng	103	20.60
33	Estimation of elastic constant of rocks using an ANFIS approach [54]	2012	Singh Rajesh; Kainthola, Ashutosh; Singh, T. N	101	25.25
34	No-reference image quality assessment using modified extreme learning machine classifier [55]	2009	Suresh S; Babu, R. Venkatesh; Kim, H. J	101	14.43
35	Development and investigation of efficient artificial bee colony algorithm for numerical function optimization [56]	2012	Li Guoqiang; Niu, Peifeng; Xiao, Xingjun	100	25.00
36	Parameter determination of support vector machine and feature selection using simulated annealing approach [57]	2008	Lin Shih-Wei; Lee, Zne-Jung; Chen, Shih-Chieh; Tseng, Tsung-Yuan	100	12.50
37	A linguistic consensus model for Web 2.0 communities [58]	2013	Alonso S; Perez, I. J; Cabrerizo, F. J; Herrera-Viedma, E	99	33.00
38	Knowledge-Based Ant Colony Optimization for Flexible Job Shop Scheduling Problems [59]	2010	Xing Li-Ning; Chen, Ying-Wu; Wang, Peng; Zhao, Qing-Song; Xiong, Jian	98	16.33
39	Path planning for autonomous mobile robot navigation with ant colony optimization and fuzzy cost function evaluation [60]	2009	Garcia M. A. Porta; Montiel, Oscar; Castillo, Oscar; Sepulveda, Roberto; Melin, Patricia	97	13.86
40	A fuzzy AHP approach to personnel selection problem [61]	2009	Gungor Zulal; Serhadlioglu, Guerkan; Kesen, Saadettin Erhan	94	13.43

Applied Soft Computing is a journal of high impact factor, viz., 3.541. Impact factor is a generally accepted metric for assessment of journals. It represents the average citation of papers published in the journal during last two (five) years. ASOC has been publishing good quality research work in the area of computer science and engineering. The top 40 most cited papers in

ASOC according to WoS are shown in Table 3. The top cited publication is titled, *On the performance of artificial bee colony (ABC) algorithm,* by Karaboga and Basturk [23]. The paper has received 1073 citations since its publication in 2008. The third rank is also taken by Karaborga et al. [24] with 302 citations, with the paper titled *A novel clustering approach: Artificial Bee Colony (ABC) algorithm*. The second place with 350 citations goes to Mallipeddi et al. [22] for their paper, *Differential evolution algorithm with ensemble of parameters and mutation strategies.* They are followed by Wei [25] with 277 citations, Rajabioun [26] with 183 citations and Singh [27] with 179 citations for their work on, *intuitionistic fuzzy information and their application, Cuckoo Optimization Algorithm, and artificial bee colony algorithm for the leaf-constrained minimum spanning tree*, respectively.

In terms of citations per year, the paper by Karaboga and Basturk [23] performed best with 134.13 citations per year, and next is Mallipeddi et al. [22] with 70 citations per year.

4. AUTHORS AND INSTITUTION ANALYSIS

This Section analysis the authorship of the ASOC publications and their institutions. It also discusses about the authors who were cited highly in the ASOC publications as well as their co-citation network.

4.1 *Authorship*

Table 4 shows the list of top 15 productive and influential authors in ASOC. Each of the authors have contributed more than 10 papers in ASOC. Pedrycz, Castillo with 25 and 22 papers respectively, are the three top most productive authors. They are followed by Jiao (19), Melin (15), Chang (14), Wang, Y. (14), Ghosh (13), Wang S.T. (13), Isa (12) and Lin (12).

Table 4: Most Productive and Influential Authors in ASOC (2004-2016)

Rank	Name	TP	TC	CPP	h-index
1	Pedrycz W	25	274	10.96	9
2	Castillo O	22	761	34.59	14
3	Jiao LC	19	154	8.11	8
4	Melin P	15	684	45.60	12
5	Chang PC	14	351	25.07	10
6	Wang Y	14	434	31.00	7
7	Ghosh S	13	108	8.31	6
8	Wang ST	13	87	6.69	6
9	Isa Nam	12	106	8.83	8
10	Lin SW	12	249	20.75	7
11	Zarandi MHF	12	123	10.25	5
12	Kumar A	11	91	8.27	4
13	Li H	11	77	7.00	4
14	Lim CP	11	107	9.73	5
15	Zhang J	11	58	5.27	4

Besides total number of papers, total citations, citations per paper and h-index are also used to describe the authors. Authors with the highest total citations are Castillo (761), Melin (684), Wang Y. (434), Chang (351) and Pedrycz (274). Few of the highly cited papers contributed by these authors are: The design and optimization of Interval type-2 fuzzy controllers [39] and autonomous mobile robot navigation with ant colony optimization and fuzzy cost function evaluation [59], A new chaos-based fast image encryption algorithm [27], Fuzzy hierarchical

TOPSIS for supplier selection [33], and Ant Colony Optimization for Flexible Job Shop Scheduling Problems [59].

The highest *average citations per paper* (CPP) were received by Melin (45.6), Castillo (34.6), Wang (31.0), Chang (25.1), Lin (20.8) and Pedrycz (11). The *h-index* was highest for Castillo (h=14), followed by Melin (12) and Chang (10).

4.2 *Institutions*

Table 5 presents the most active institutions which have contributed to ASOC publications. The Islamic Azad University, Iran produced 96 total papers with total citation of 1134. The second spot is taken by Amir Kabir University of Technology, also from Iran, with 76 papers. Jadavpur University from India takes the third spot with 47 occurrences. The total papers from the institute with total citations and citations per paper (CPP) are also given in the table, along with h-index of each institution.

Table 5: Most Productive and Influential Institutions in ASOC publications (2004-2016)

Rank	Institution	Country/ Territory	TP	TC	CPP	h-index
1	Islamic Azad University	Iran	96	1134	11.81	17
2	Amirkabir University of Technology	Iran	76	1047	13.78	16
3	Jadavpur University	India	47	780	16.60	17
4	Indian Institute of Technology IIT Kharagpur	India	46	822	17.87	17
5	University of Tehran	Iran	46	686	14.91	14
6	National Taiwan University of Science Technology	Taiwan	42	659	15.69	14
7	University of Granada	Spain	42	499	11.88	11
8	Iran University Science Technology	Iran	40	691	17.28	14
9	Hong Kong Polytechnic University	Hong Kong	39	343	8.79	11
10	Indian Institute of Technology IIT Delhi	India	36	387	10.75	11
11	Xidian University	China	35	274	7.83	10
12	Indian Statistical Institute	India	33	290	8.79	11
13	Sharif University of Technology	Iran	31	333	10.74	10
14	Universiti Teknologi Malaysia	Malaysia	31	298	9.61	10
15	Nanyang Technological University	Singapore	30	801	26.70	10
16	City University of Hong Kong	Hong Kong	28	482	17.21	11
17	University of Alberta	Canada	28	283	10.11	9
18	Yuan Ze University	Taiwan	28	531	18.96	14
10	King Abdulaziz University	Saudi Arabia	27	202	7.48	7
20	Universiti Sains Malaysia	Malaysia	27	293	10.85	10
21	Chinese Academy of Sciences	China	25	266	10.64	9
22	Polish Academy of Sciences	Poland	25	275	11.00	9
23	Universiti Malaya	Malaysia	25	197	7.88	6
24	Huazhong University of Science Technology	China	24	250	10.42	9
25	Dalian University of Technology	China	23	410	17.83	8

The two top institutes from Iran also had the highest total citation (1134, 1047) followed by the Indian Institute of Technology Kharagpur and Jadavpur University (822, 780 citations), both from India. Following is the Iran Institute of Science and Technology (691), again from Iran.

The institutes with the highest average citation per paper CPP were Nanyang Technological University, Singapore (26.7), Yuan Ze University, Taiwan (19.0), IIT Kharagpur (17.9), Dalian

University of Technology (17.8), Iran University Science Technology (17.3), Jadavpur University (16.6), National Taiwan University of Science Technology (15.7) and University of Tehran (14.9). Three institutes have an h-index of 17, Islamic Azad University, Jadavpur University and IIT Kharagpur, while Amirkabir University has an h-index of 16.

4.3 *Authors Highly Cited in ASOC*

The authors most cited by Applied Soft Computing papers are shown in Table 6. The top spot is taken by Zadeh with 728 citations, followed by Deb with 661 citations at second place, and Kennedy with 621 citations at third place. This observation is also evident from the co-citation network of the authors in ASOC (Fig. 3) as the nodes represented by these three authors are the largest in size. As explained in the next section, the colored clusters in Fig. 3 indicate different research themes. Zadeh belonging to soft computing applications, Deb to multi-objective optimization problem and Kennedy to particle swarm optimization.

Table 6: Authors most cited by ASOC papers during (2004-2016)

Rank	Author Name	Citations
1	Zadeh LA	728
2	Deb K	661
3	Kennedy J	621
4	Xu ZS	406
5	Karaboga D	403
6	Dorigo M	391
7	Goldberg DE	372
8	Zitzler E	335
9	Yager RE	261
10	Storm R	251
11	Pedrycz W	219
12	Yildiz AR	216
13	Yang XS	216
14	Herrera F	210
15	Ishibuchi H	205

4.4 *Author Co-citation Network*

Fig. 3 illustrates the author co-citation network created from the references in the ASoC papers published during 2004 to 2016, using VOSviewer. Each node represents a referenced author and the size of a node represents the number of citations to that author. The line connecting two nodes in the network represents a co-citation relation, i.e., it shows that the two authors are cited together in the reference list of an ASOC paper. If certain authors are cited together more often, their papers are likely to be similar in content and the software places them closer on the map. Clusters of related authors can be identified in the network since the more frequently co-cited authors would belong to the same cluster representing a common research theme. This network essentially represents the knowledge base from which ASoC papers are derived.

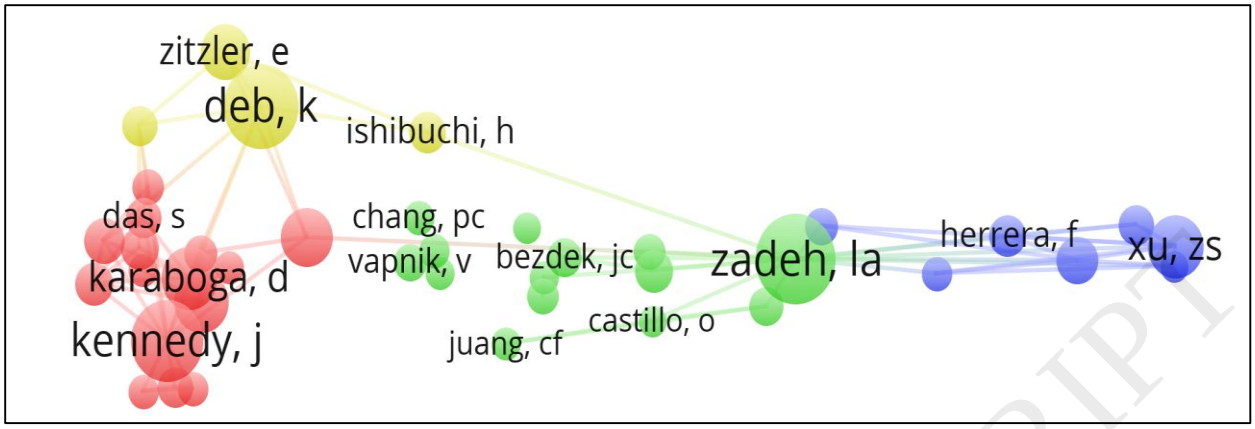

Fig. 3: Author Co-Citation network of ASOC (2004-2016)

The graph is strongly connected showing that most authors have been co-cited with one-another. However, the green cluster consisting of Zadeh, Castillo, Bezdek, Chang has been mutually co-cited more than with others. This research area is likely to be more central to the knowledge pool in ASOC. The size of the nodes reflects the number of papers in the references attributed to the respective authors. The main clusters of co-cited authors and the research areas they represent are:

1) Zadeh, Castillo, Bezdek, Chang – Soft Computing applications
2) Deb, Ishibuchi, Zitzler and another author – Multi-objective optimization problem
3) Xu, Herrera and others – Decision making
4) Karaboga, Kennedy, Das and others – Particle swarm optimization

5. COUNTRY ANALYSIS OF APPLIED SOFT COMPUTING PUBLICATIONS

As Applied Soft Computing is a leading journal in the area, a number of researchers from the computer science fraternity have published their important research work there. The top 25 countries/territories from where papers were received are shown in Table 7. The countries are ranked according to the number of papers published; other indicators such as total citations, citations per paper and h-index are also mentioned.

According to the data from the Table 7, Peoples Republic of China is the most productive country with 682 papers followed by India (612), Iran (403), Taiwan (333), Spain (278), USA (222) and Turkey (212). In terms of total citations, China has the highest citations (8468) followed by India (8007), Iran (4963), Taiwan and Turkey (4556 each), USA (2786), Spain (2510), and England (2525). However, when it comes to citations per paper, Singapore stands out with 23.85 citations per paper, followed by Turkey with 21.49 cites/paper. Something worth noticing is that the top three positions are held by developing countries. Moreover, in the top 10 list, five places are occupied by developing countries, indicating their contribution. In terms of h-index that measures both quantity and quality, India has the highest, h=42, followed by China, h=40.

Table 7: ASOC papers (2004-2016): Most Productive Countries

Rank	Country/Territory	TP	TC	CPP	h-index

1	Peoples R China	682	8468	12.42	40
2	India	612	8007	13.08	42
3	Iran	403	4963	12.32	33
4	Taiwan	333	4556	13.68	32
5	Spain	278	2510	9.03	24
6	USA	222	2786	12.55	26
7	Turkey	212	4556	21.49	28
8	England	186	2525	13.58	26
9	Malaysia	149	1470	9.87	21
10	Canada	137	1591	11.61	21
11	Italy	86	737	8.57	12
12	Australia	84	1060	12.62	17
13	Brazil	80	645	8.06	13
14	Mexico	78	1229	15.76	18
15	Japan	77	539	7.00	14
16	Poland	71	635	8.94	15
17	France	69	526	7.62	12
18	South Korea	69	696	10.09	13
19	Saudi Arabia	67	426	6.36	10
20	Germany	56	515	9.20	11
21	Singapore	47	1121	23.85	14
22	Greece	45	769	17.09	16
23	Pakistan	41	310	7.56	10
24	Finland	33	483	14.64	13
25	Portugal	31	248	8.00	10

Fig. 4 shows the bibliographic coupling of the top 20 most productive countries/territories. When the reference lists of two papers have some common entries, the papers are said to be bibliographically coupled. The higher the intersection, or degree of overlap between the reference lists, the greater the coupling. The concept extended to countries would imply that two countries are bibliographically coupled if there is a degree of overlap between the papers cited by them. The clusters in Fig. 4 show that the China, India, Iran, Taiwan, Turkey, Brazil, Australia and Malaysia belong to a single red cluster and are likely to be working on similar research themes and citing the same literature in their reference lists or bibliography. USA, England, Spain, France, Germany, Italy, Mexico and Japan form another cluster, the green cluster. Canada, Saudi Arabia, South Korea and Poland form the blue cluster.

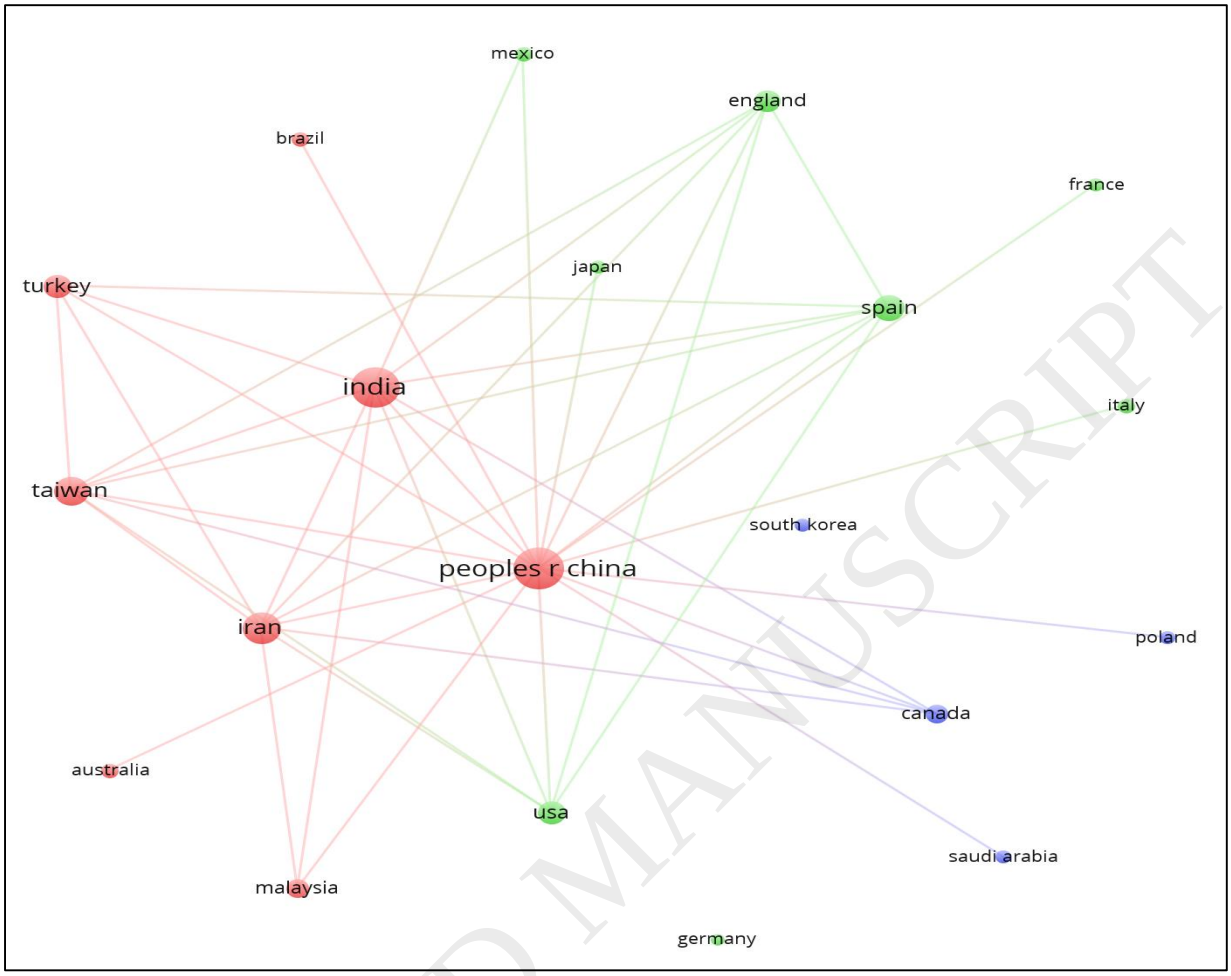

Fig. 4: Bibliographic Coupling of the 20 most productive countries/territories in ASOC Publications during (2004-2016)

5.1 *Country Collaboration*

Co-authorship is an interesting feature in the development of research disciplines and publications. They are a measure of collaboration and knowledge exchange which can be considered at the level of individuals, institutions or countries. Fig. 5 shows the co-authorship of the ASOC publications between countries/territories. Each node in the network represents a country and each edge between two nodes represents collaboration. The size of a node corresponds to the number of co-authored papers produced by that particular country.

China, Taiwan and USA form the yellow cluster, indicating that they collaborate more with one another than with other countries. Similarly, India, Iran, Malaysia, England, Turkey, Australia, Japan and Singapore form a red cluster implying that they collaborate primarily with each other. The green cluster has lower levels of collaboration and includes Canada, Poland, South Korea and Pakistan. The remaining countries, Spain, Germany, France and Italy form the blue cluster and have visible co-authorships.

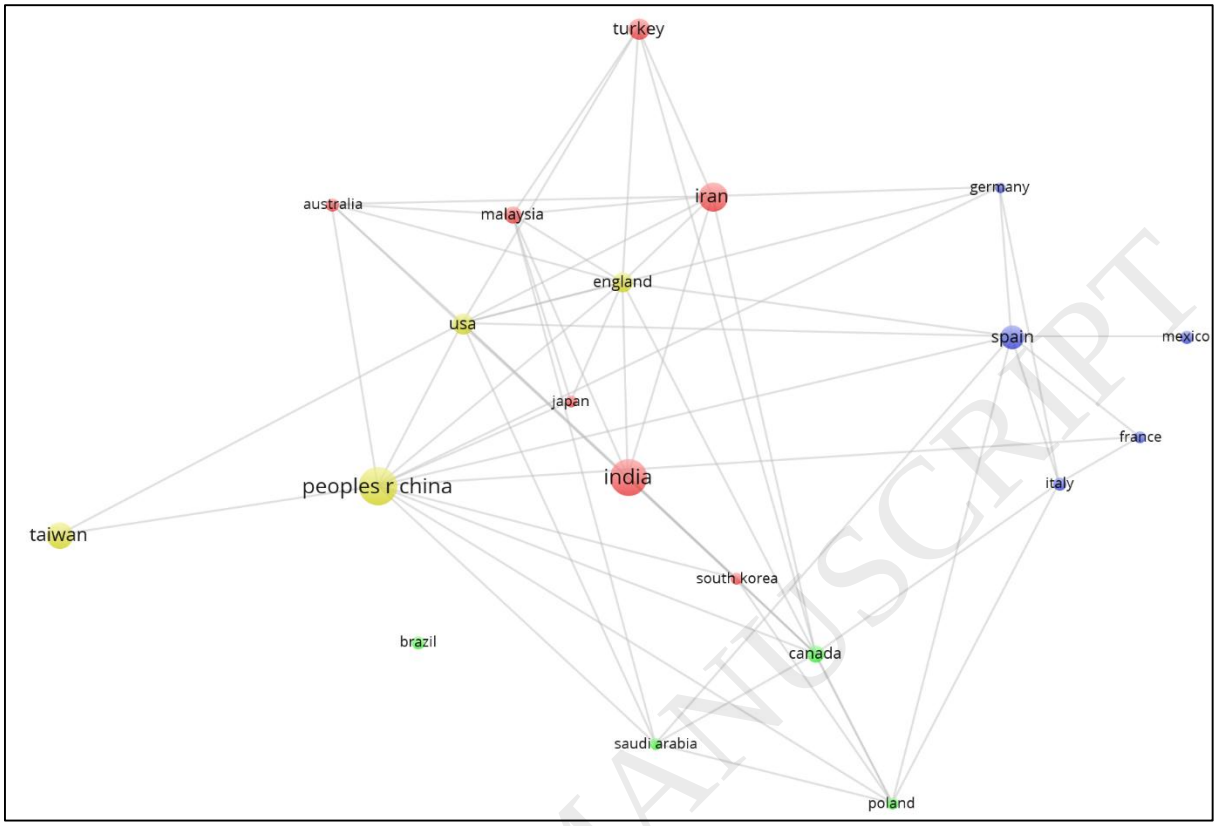

Fig. 5: Country co-authorship of the ASOC publications during (2004-2016)

5.2 *Temporal Analysis*

Temporal analysis of the literature serves to identify productive and influential countries at various stages and can give some insight into research trajectories of different countries. Table 8 shows the leading countries in four different stages (2004-2007, 2008-2010, 2011-2013, and 2014-2016). From the analysis, over these time periods, we find that there has been a rise or fall in the relative ranks of countries as measured by their output in ASOC. In the first two stages India was leading with a total of 128 publications but in the later two stages China overtook India and is now the leading contributor. Western countries such as USA and England were among the top five in 2004-07 with a total of 42 papers, while Asian countries in the top 5 had 75 papers. In the next phase 2008-10, USA had 31 papers, while of the remaining countries three were Asian and had 190 papers. One Arab country, Iran had 39 papers. In the next phase, Europe returns as Spain with 114 papers, Asia had 609 papers, while Iran had 156 papers. In the last phase, Asia had 645 papers, European countries Spain and Turkey had 264 papers while Iran had 205 papers.

Something worth noticing is the CPP of China, which has been the highest during 2004-07, 2011-13, and 2014-16. However, during 2008-2010, Iran had the highest CPP. In terms of h-index, India had the highest (h=18) in 2004-07, USA had the highest in 2008-10 (h=31), China had the highest (h=32) in 2011-13, and again (h=19) in 2014-16.

Table 8: Most Productive and Influential Countries in Four Different Temporal Stages

Years	Country/Territory	TP	TC	CPP	h-index
2004-2007	India	42	1126	26.81	18
	USA	23	515	22.39	12
	England	19	510	26.84	11
	Japan	17	208	12.24	11
	China	16	499	31.19	11
2008-2010	India	86	2399	27.90	25
	China	59	1811	30.69	24
	Taiwan	44	1254	28.50	18
	Iran	39	1278	32.77	23
	USA	31	749	24.16	31
2011-2013	China	226	4217	18.66	32
	India	220	3293	14.97	29
	Taiwan	163	2478	15.20	26
	Iran	156	2795	17.92	26
	Spain	114	1490	13.07	19
2014-2016	China	381	1941	5.09	19
	India	264	1189	4.50	16
	Iran	205	844	4.12	13
	Spain	142	622	4.38	12
	Turkey	122	536	4.39	12

6. Document co-citation analysis

The thematic areas of ASOC publications are also explored using Citespace (*see* details in methodology, Section 2). Fig. 6 shows the document co-citation clusters of ASOC publications. The title term of each cluster is determined by Citespace using log-likelihood ratios. For ASOC publications, there were a total of 117 clusters out of which the top 10 are shown in Table 9 along with the top term from log-likelihood ratios.

Table 9: Cluster Analysis

Cluster id	Size	Mean(Year)	Topic
0	47	2004	radial basis function network
1	44	2003	application area
2	43	2006	adaptive parameter selection
3	41	2007	differential evolution
4	37	2008	artificial bee colony algorithm
5	36	2006	fuzzy cognitive map
6	29	2008	job shop scheduling problem
7	28	2002	chaotic sequence
9	25	2005	intuitionistic fuzzy entropy measure

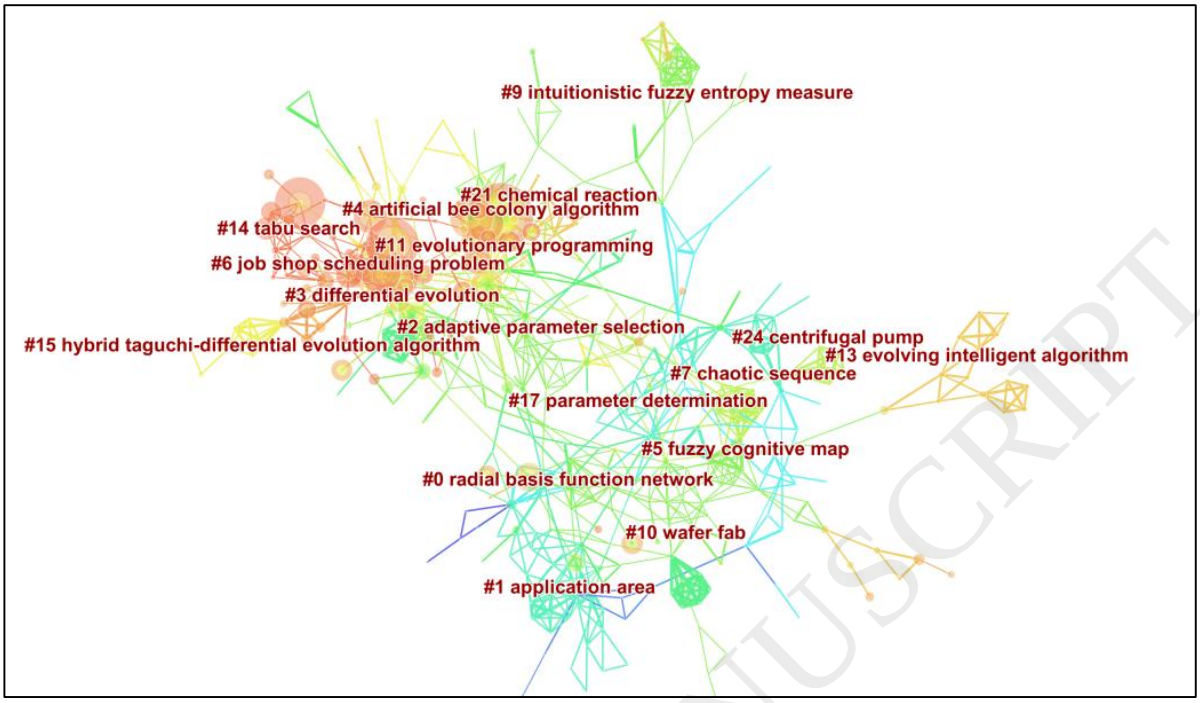

Fig. 6: Document co-citation clusters

From Table 9 and Figure 6 it is evident that the largest clusters are *radial basis function network*, *application area* and *adaptive parameter selection*. The oldest cluster is *chaotic sequence* in 2002 and the youngest clusters are *artificial bee colony algorithm* and *job shop scheduling problem.*

Table 10 shows the top 19 papers highly cited by ASOC publications with co-citation frequency of over 70. It indicates the knowledge core from which papers in ASOC are derived. The paper by Kennedy and Eberhart on *Particle Swarm Optimization (PSO)* is on top of the list with 347 citations, which also gives an idea that out of the total of 3680 ASOC publications 376 (~10%) were in some way based on PSO, i.e., it has had the greatest influence on research publications in ASOC. Zadeh's seminal paper on *Fuzzy sets* [2] with 267 citations comes next. The book by Goldberg on *Genetic Algorithms* [63] has been cited 243 times in ASoC since its publication in 1989 and ranks third. The book by Holland on *Adaptation in natural and artificial systems* [64], and the paper by Deb *et al.* on *Multiobjective Genetic Algorithms* [65], stand at fourth and fifth positions with 164 and 158 citations, respectively. Most of the highly cited references were published before 2000 except Deb [65], Eberhart et al. [76] in 2001, and Deb [69] in 2001, Clerc & Kennedy [73] in 2002, and Karaboga & Basturk [23] in 2008.

Table 10: Top 19 Highly Cited References with Co-Citation Frequency of over 70 times

Rank	Authors	Title	Source	Year	Frequency
1	J. Kennedy and R. Eberhart	Particle Swarm Optimization [62]	IEEE International Conference on Neural Networks Proceedings	1995	347
2	L. A. Zadeh	Fuzzy sets [2]	Information and Control	1965	267
3	D. E. Goldberg	Genetic algorithms in search, optimization, and machine learning [63]	Book	1989	243
4	J. H. Holland	Adaptation in natural and artificial systems. An introductory analysis with application to biology, control, and artificial intelligence [64]	Book	1975	164
5	K. Deb, A. Pratap, S. Agarwal & T. Meyarivan	A fast and elitist multi-objective genetic algorithm: NSGA-II [65]	IEEE Transactions on Evolutionary Computation	2002	158
6	R. Storn & K. Price	Differential Evolution – A Simple and Efficient Heuristic for global Optimization over Continuous Spaces [66]	Journal of Global Optimization	1997	155
7	T. Takagi & M. Sugeno	Fuzzy identification of systems and its applications to modeling and control [67]	IEEE Transactions on Systems, Man, and Cybernetics	1985	115
8	S. Kirkpatrick, C. D. Gelatt & M. P. Vecchi	Optimization by Simulated Annealing [68]	Science	1983	107
9	K. Deb	Multi-objective optimization using evolutionary algorithms [69]	Book	2001	106
10	L. A. Zadeh	The concept of a linguistic variable and its application to approximate reasoning—I [70]	Information Sciences	1975	98
11	J. S. R. Jang	ANFIS: adaptive-network-based fuzzy inference system [71]	IEEE Transactions on Systems, Man, and Cybernetics	1993	96
12	J. C. Bezdek	Pattern Recognition with Fuzzy Objective Function Algorithms [72]	Book	1981	95
13	M. Clerc & J. Kennedy	The particle swarm - explosion, stability, and convergence in a multidimensional complex space [73]	IEEE Transactions on Evolutionary Computation	2002	93
14	V. N. Vapnik	The nature of statistical learning theory [74]	Book	1995	93
15	M. Dorigo, V. Maniezzo & A. Colorni	Ant system: optimization by a colony of cooperating agents [75]	IEEE Transactions on Systems, Man, and Cybernetics	1996	82
16	R. C. Eberhart,Y. Shi & J. Kennedy	Swarm Intelligence [76]	Book	2001	74
17	T. L. Saaty	Analytic Hierarchy Process [77]	Book	1980	72
18	D. Karaboga & B. Basturk	On the performance of artificial bee colony (ABC) algorithm [23]	Applied Soft Computing	2008	71
19	J. R. Koza	Genetic programming: on the programming of computers by means of natural selection [78]	Book	1992	71

7. DISCUSSION AND CONCLUSION

In this paper, we have explored the 12 year (2004-2016) publications and citation history of the journal Applied Soft Computing using bibliometric methods and techniques to exhibit an aerial view and hidden publication structure of the ASOC. It is the youngest of several journals in similar and neighbouring areas, shown in Table 11. It ranks 2nd in terms of number of papers

and citations, 3rd in terms of number of citations per paper after TFS and INS, and 4th in terms of Impact Factor in a 10 year comparison.

Table 11: ASOC comparison with other related Journals

Journal	Induction Year	TP (10 years)	TC (10 years)	CPP	Impact Factor
Information Sciences (INS)	1968	5125	102308	20.0	4.832
Soft Computing (SC)	1997	1620	14096	8.7	2.472
Knowledge-Based Systems (KBS)	1987	2092	31516	15.1	4.529
Engineering Applications of Artificial Intelligence (EAAI)	1988	1617	22107	13.7	2.894
IEEE Transactions on Fuzzy Systems (IEEE TFS)	1993	1186	42013	35.4	7.651
Applied Soft Computing (ASOC)	2001	3581	56584	15.8	3.541

The bibliographic details of a total of 3680 papers were analyzed (~ 306 per year). ASOC published the largest number of papers in 2015 (654) and received the highest total citations in the year 2011 (10553). Four papers received more than 200 citations each, while ~15% papers still remain uncited.

The most productive and influential authors in ASOC were Pedrycz, University of Alberta, Castillo, Tijuana Institute of Technology and Jiao, Xidian Univeristy . The top research areas in the last five years in ASoC were *GAs, PSO and Multi-Objective Optimization MOO*. Islamic Azad University and Amirkabir University of Iran take first two ranks in the list of most productive institutions. Zadeh, University of California at Berkeley, Deb, Michigan State University, and Kennedy, Bureau of Labor Statistics hold the top positions as the individuals most cited by ASOC authors. Among countries, China, India and Iran are the top 3 most productive countries.

This study is a scientometric and bibliometric study of the ASOC journal, however, the limitation of this research area arises from the 'metric' aspect of the discipline. It deals with numbers of papers and citations. Numbers represent 'quantity', but citations do not unambiguously represent 'quality'. It is known that citations are subject to the biblical 'Matthew'effect which says, 'to whom it had been given, to him shall be given more' [79]. Also it has been seen that high productivity has been linked to high citations. The implication is that isolated highly cited papers by an author can be missed in studies that cumulate citations. The second limitation is that studies often cover a period of 10-25 years. If a paper is not cited within a short span of time after publication it is likely to be missed. This means that 'sleeping beauties' or those papers which pick up a significant number of citations after a long dormant phase are also likely to escape the attention of scientometricians [80].

Another limitation of the study is that it creates a profile of a journal but not that of the field it covers, which may be peopled by other journals, authors, institutions and countries. Certain limitations are inherent to the data retrieved from the WoS database. For example, not all journals are indexed in WoS. Citations from journals outside the ambit of WoS would be missed giving ASOC fewer citations than it has actually received.

In general, this paper provides the overall publication outline since the introduction of ASOC. It has played an important role in shaping the academic research. ASOC is certainly discovering developing trends in the domain of soft computing.

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