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A citation analysis overview of fuzzy research journals

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ABSTRACT

The publication of bibliometric studies has gained significative relevance and popularity in the last years. This fact is mainly triggered by the flexibility and dynamism that new information technologies provide. For our case, the structured gathered material thoroughly refined offers a wide scope of the contributions that have shaped the diverse areas of research that Fuzzy methods consider, e.g. mathematics, computer science, engineering, operations research, automation and control systems, business economics, management, among several others. The purpose of the present paper is to aid the visualization of the relations that authors, publication years and research areas hold together utilizing bibliometric techniques. The focus of the study relies on 8 of the most cited journals in the field of Fuzzy Research. By performing the citation analyses of the selected journals in Thomson Reuters Web of Science database, we seek on the one hand, high reliability of the retrieved data by adding only information that is indexed in the core collection of the catalogue, and on the other, information regarding the connections of these journals, the influence that each one has over the rest, and the authors that continuously generate citations for the specified publications.

1. INTRODUCTION

Fifty-three years have passed since the first publication of Fuzzy Logic research. The work, "Fuzzy Sets" issued in Information and Control by Professor Lofti A. Zadeh in 1965 [1], opened the path for a novel perspective in several fields of sciences e.g. artificial intelligence, computer science, medicine, control engineering, decision theory, expert systems, logic, management science, operations research, pattern recognition, robotics, among others [2-3]. Much of the popularity of the Fuzzy Sets Theory relies on the intuitive approach concerning subjective, ambiguous, non-clear or non-well-defined problems. This characteristic feature allows scientists to generate new insights to phenomena that cannot be well represented using traditional methods.

In our days, numerous Fuzzy specialized journals exist, assembling the scientific products of authors all over the world. The increasing influence of Fuzzy Logic demands an analysis that sheds light into the rapid evolution of the proposed concept, techniques and models. The journals selected for the bibliometric analyses in our study are: 1) Fuzzy Sets and Systems (FSS); Netherlands, 2.783*, 2) Expert Systems with Applications (ESA); USA, 3.526*, 3) Information Sciences (IS); USA, 4.732*, 4) Knowledge Based Systems (KBS); Netherlands, 4.627*, 5) International Journal of Approximate Reasoning (IJAR); USA, 2.948*, 6) Applied Soft Computing (ASC); Netherlands, 3.811*, 7) International Journal of Intelligent Systems (IJIS); USA, 2.795*, and 8) International Journal of Uncertainty Fuzziness and Knowledge Based Systems (IJUFKS); Singapore, 1.232*. *Thomson Reuters Journal Citation Reports 5-year impact factor. All together, these journals compile over 97,000 citations and represent some of the most influential Fuzzy Research Journals in the world. The selection process was conducted selecting some of the most influential papers described in Merigó, Gil-Lafuente, and Yager [4].

The objective of the present paper is to generate a citation analysis using bibliometric techniques on eight highly cited Fuzzy research journals. The aim is to advance in the knowledge of the trends that connect the selected journals by focusing on the top citing authors, the publication years of the citations, the top research areas citing the journals and a novel crossed-reference journal by journal analyses that addresses to the question, *which journal is citing which?* in Fuzzy Research. Along to the natural results of compiling and representing large amounts of data in convenient tables, this study offers additional implications including the visualization on the conformation or association of research groups and possible synergies between researchers, leading journals per time-period, top research areas that explore fuzzy techniques and new opportunities for applications in emerging research areas.

The reminder is as follows. Section 2 presents the methodology that guides our study. Section 3 presents the results obtained, firstly introducing results for each of the selected journals, following, the cross-referenced journal by journal results and the results for the top influential authors.

2. METHODOLOGY

One highly important issue when conducting bibliometric studies is the need of neutral and objective search processes

along with a proper selection of data sources and a clear refinement of the results.

In this study, we present data retrieved form the core collection of the Thomson & Reuters Web of Science database (WoS). This database comprises high quality journals that have rigorous standards for publication, thus ensuring a reliable source of information. The data was retrieved following the next steps: firstly, search for publication name i.e. "Fuzzy Sets and Systems", "Expert Systems with Applications", "Information Sciences", "Knowledge-Based Systems"; "International Journal of Approximate Reasoning", "Applied Soft Computing", "International Journal of Intelligent Systems", and "International Journal of Uncertainty Fuzziness and Knowledge-Based Systems", limiting the search for the years 1900 to 2017. Note that information from 2017 is included. Following, a search filter was used, considering only articles, reviews, letters or notes. Finally, we perform a citation analyses and retrieve the information for authors, research area, years and selected data to build the cross – referenced journal by journal table. The search was carried out from January 2018 until March 2018. This study classifies the material using the approach found in Merigó, Gil-Lafuente, and Yager, [5]. The information presented in the individual journal tables is structured in three main categories: Authors, years and research Areas. The top 15 results are shown for each category.

3. RESULTS

Based on the steps proposed in the previous section, a total of 38,532 papers were published by the 8 selected journals. Together they sum up 765,073 cites. A total of 276,487 papers were found to cite the selected journals.

3.1 Individual journal results

The individual results of each journal present a total of 14,212 cites from 48 different authors. In general, ZS Xu leads the count with 1,572 cites, followed by W Pedrycz with 1,564; F Herrera, 1,076; RR Yager, 821; and E Herrera-Viedma with 609. For a deep visualization of the authors influence please see Table 10.

For the category of years, the most productive year was 2017, with a total of 46,237 papers citing the journals, then 2016 with 40,980, following, 2015, 33,706; and 2014 with 27,297. There is a total of 34 Research Areas comprising 394,919 studies. The most influential area is Computer Science with a total of 156,621 studies, Engineering 88,187; Mathematics 37,116; Operations Research Management Science 29,885; Automation Control Systems 17,478; and Business Economics with 12,809 The specific results for each journal are displayed in the next Tables 1-8.

Table 1. Fuzzy sets and systems

R	Author	Total	Year	Total	Research Area	Total
1	W Pedrycz	547	2017	4984	Computer Science	30415
2	ZS Xu	297	2016	4731	Engineering	14623
3	RR Yager	280	2015	4062	Mathematics	13564
4	GH Huang	273	2014	3888	Op Research Management Science	4830
5	R Mesiar	272	2013	3360	Automation Control Systems	4509
6	F Herrera	211	2012	3069	Business Economics	2093
7	D Dubois	195	2011	2981	Science Technology	1545
8	SC Tong	191	2009	2530	Environmental Sciences Ecology	1416
9	B De Baets	174	2010	2507	Instruments Instrumentation	977
10	H Prade	170	2008	2198	Mechanics	899
11	SM Chen	166	2006	1851	Physics	795
12	C Kahraman	157	2007	1804	Water Resources	739
13	B Davvaz	154	2005	1460	Energy Fuels	538
14	H Bustince	139	2004	1247	Robotics	488
15	E Herrera-Viedma	135	2003	1101	Geology	472

Table 2. Expert systems with applications

R	Author	Total	Year	Total	Research Area	Total
1	EK Zavadskas	155	2017	14192	Computer Science	33730
2	ZS Xu	145	2016	13257	Engineering	30708
3	S Shamshirband	140	2015	11255	Op Research Management Science	12167
4	XH Chen	134	2014	8737	Business Economics	5625
5	C Kahraman	132	2013	6917	Mathematics	4516
6	W Pedrycz	131	2012	5509	Automation Control Systems	3620
7	A Azadeh	123	2011	4279	Science Technology Other Topics	3348
8	A Kumar	123	2010	2688	Environmental Sciences Ecology	2959
9	TP Hong	114	2018	2431	Energy Fuels	2312
10	GH Huang	112	2009	1904	Instruments Instrumentation	1774
11	Y Deng	110	2008	999	Telecommunications	1736
12	F Herrera	105	2007	609	Information Science Library Science	1504
13	D Petkovic	104	2006	484	Chemistry	1477
14	SM Chen	102	2005	386	Materials Science	1464
15	Q Zhang	101	2004	319	Physics	1395

Table 3. Information sciences

R	Author	Total	Year	Total	Research Area	Total
1	W Pedrycz	383	2017	11269	Computer Science	41157
2	ZS Xu	292	2016	9530	Engineering	18843
3	F Herrera	252	2015	7702	Mathematics	10463
4	RR Yager	233	2014	6217	Op Research Management Science	5197
5	B Davvaz	182	2013	4890	Automation Control Systems	5162
6	YM Li	180	2012	4027	Telecommunications	2257
7	P Shi	177	2011	3173	Science Technology	2217
8	O Castillo	160	2018	2570	Business Economics	1882
9	CC Chang	148	2010	2474	Physics	1608
10	C Kahraman	141	2009	2199	Instruments Instrumentation	1400
11	JM Zhan	140	2008	1676	Mechanics	1024
12	D Dubois	137	2007	1332	Environmental Sciences Ecology	965
13	E Herrera-Viedma	132	2006	1187	Chemistry	800
14	H Prade	125	2005	895	Energy Fuels	746
15	H Bustince	123	2004	747	Mathematical Comp Biology	680

Table 4. Knowledge-based systems

R	Author	Total	Year	Total	Research Area	Total
1	ZS Xu	155	2017	4451	Computer Science	12634
2	XH Chen	107	2016	3670	Engineering	5214
3	UR Acharya	89	2015	2592	Op Research Management Science	1998
4	Y Deng	87	2014	1857	Mathematics	1287
5	F Herrera	84	2013	1306	Business Economics	1036
6	W Pedrycz	84	2018	1042	Automation Control Systems	772
7	JQ Wang	84	2012	1039	Science Technology	737
8	GW Wei	79	2011	723	Telecommunications	445
9	H Fujita	74	2010	496	Information Science Library Science	432
10	Y Zhang	74	2009	408	Environmental Sciences Ecology	396
11	E Herrera-Viedma	72	2008	314	Physics	310
12	PD Liu	71	2007	244	Energy Fuels	292
13	HY Chen	64	2006	242	Mathematical Computational Biology	259
14	LG Zhou	63	2005	210	Medical Informatics	253
15	TR Li	62	2004	199	Psychology	224

Table 5. International journal of approximate reasoning

R	Author	Total	Year	Total	Research Area	Total
1	ZS Xu	179	2017	1637	Computer Science	9121
2	F Herrera	141	2016	1494	Engineering	2801
3	W Pedrycz	140	2015	1399	Mathematics	2026
4	D Dubois	81	2014	1275	Op Research Management Science	1068
5	R Mesiar	80	2013	977	Automation Control Systems	614
6	E Herrera-Viedma	77	2012	942	Business Economics	408
7	RR Yager	71	2011	861	Science Technology	406
8	H Bustince	67	2010	651	Environmental Sciences Ecology	265
9	B De Baets	59	2009	598	Telecommunications	128
10	T Denoeux	59	2008	479	Mathematical Computational Biology	123
11	H Prade	58	2007	354	Instruments Instrumentation	119
12	GW Wei	58	2006	329	Physics	116
13	TR Li	51	2018	322	Robotics	113
14	L Martinez	49	2005	303	Water Resources	113
15	A Skowron	48	2004	256	Medical Informatics	109

Table 6. Applied soft computing

R	Author	Total	Year	Total	Research Area	Total
1	W Pedrycz	135	2017	7501	Computer Science	15527
2	O Castillo	100	2016	6164	Engineering	11851
3	ZS Xu	89	2015	4855	Op Research Management Science	2880
4	XH Chen	86	2014	3656	Mathematics	2419
5	A Kumar	82	2013	2605	Automation Control Systems	1941
6	P Melin	82	2012	1760	Science Technology	1540
7	EK Zavadskas	77	2018	1687	Energy Fuels	1335
8	GW Wei	76	2011	1242	Business Economics	917
9	S Shamshirband	71	2010	678	Mechanics	903
10	A Abraham	69	2009	499	Environmental Sciences Ecology	827
11	LC Jiao	68	2008	235	Telecommunications	814
12	F Herrera	67	2007	117	Instruments Instrumentation	791
13	JQ Wang	66	2006	53	Materials Science	717
14	Y Deng	63	2005	27	Physics	642
15	PD Liu	61	2004	3	Chemistry	613

Table 7. International journal of intelligent systems

R	Author	Total	Year	Total	Research Area	Total
1	ZS Xu	275	2017	1189	Computer Science	8278
2	RR Yager	177	2016	1158	Engineering	2448
3	F Herrera	147	2015	991	Mathematics	1375
4	E Herrera-Viedma	110	2014	892	Op Research Management Science	1004
5	JM Merigó	99	2013	751	Automation Control Systems	543
6	XH Chen	91	2012	651	Business Economics	463
7	W Pedrycz	85	2011	624	Science Technology	286
8	GW Wei	74	2010	529	Environmental Sciences Ecology	162
9	JQ Wang	71	2009	499	Robotics	140
10	L Martinez	68	2008	429	Information Science Library Science	120
11	H Bustince	66	2007	353	Physics	98
12	HY Chen	64	2006	347	Neurosciences Neurology	96
13	V Torra	61	2005	296	Medical Informatics	90
14	PD Liu	59	2018	270	Psychology	88
15	D Dubois	58	2003	258	Telecommunications	88

Table 8. International journal of uncertainty, fuzziness and knowledge-based systems

R	Author	Total	Year	Total	Research Area	Total
1	ZS Xu	140	2017	1014	Computer Science	5759
2	R Mesiar	113	2016	976	Engineering	1699
3	E Herrera-Viedma	83	2015	850	Mathematics	1466
4	JM Merigó	83	2014	775	Op Research Management Science	741
5	GW Wei	83	2013	698	Business Economics	385
6	F Herrera	69	2011	584	Automation Control Systems	317
7	B De Baets	64	2012	554	Telecommunications	245
8	V Torra	60	2009	408	Science Technology	216
9	RR Yager	60	2010	405	Environmental Sciences Ecology	137
10	W Pedrycz	59	2008	323	Mechanics	131
11	H Bustince	50	2007	261	Physics	88
12	L Martinez	49	2006	251	Medical Informatics	83
13	XH Chen	48	2018	234	Information Science Library Science	82
14	YJ Xu	46	2005	197	Transportation	61
15	MR Meybodi	44	2004	161	Instruments Instrumentation	55

3.2 Cross reference

The cross-reference analysis allows the reader to visualize the influence that each selected journal has on the other ones. It is no surprise to see that each journal cites itself the most e.g. ASC 2,512, ESA 7,227, etc., however, IJIS and IJUFKS cite FSS more that themselves, with 643 and 701 papers respectively. In general, the journal that has been cited the most from all the other selected journals is Information Sciences with 13,563 papers. On the other side Expert Systems with Applications has cited the most with a total of 13,338 cites.

Table 9. Cross-reference between journals

J	ASC	ESA	FSS	IJAR	IJIS	IJUFKS	IS	KBS	Total
ASC	2512	1589	930	284	257	159	1441	476	7648
ESA	1118	7227	1375	365	343	219	1709	982	13338
FSS	83	130	6081	647	472	532	2,278	73	10296
IJAR	62	95	663	954	284	219	495	100	2872
IJIS	79	159	643	271	535	176	501	116	2480
IJUFKS	76	121	701	218	224	383	429	82	2234
IS	782	1155	2071	735	583	419	5,714	653	12112
KBS	450	1044	502	335	333	179	996	1818	5657
Total	5162	11520	12966	3809	3031	2286	13563	4300	56637

3.3 Top 15 authors

Table 10 presents the top 15 most influential authors based on the information displayed in this study. Please note that this information applies only for the selected journals and for the 15 first appearances for each journal, i.e. the information may vary if a larger scale of data is retrieved or if the selection of journals is extended.

Table 10. Top 15 most influential authors

R	Author	ASC	ESA	FSS	IJAR	IJIS	IJUFKS	IS	KBS	Total
1	ZS Xu	89	145	297	179	275	140	292	155	1572
2	W Pedrycz	135	131	547	140	85	59	383	84	1564
3	F Herrera	67	105	211	141	147	69	252	84	1076
4	RR Yager			280	71	177	60	233		821
5	E Herrera-Viedma			135	77	110	83	132	72	609
6	D Dubois			195	81	58		137		471
7	XH Chen	86	134			91	48		107	466
8	R Mesiar			272	80		113			465
9	H Bustince			139	67	66	50	123		445
10	C Kahraman		132	157				141		430
11	GH Huang		112	273						385
12	GW Wei	76			58	74	83		79	370
13	H Prade			170	58			125		353
14	B Davvaz			154				182		336
15	B De Baets			174	59		64			297

4. CONCLUSIONS

The study presents a citation analysis performed for 8 different WoS indexed fuzzy research journals. The main results are shown in three sections, the first one, shows the individual results of each selected journal. The second presents a cross-reference journal by journal table that answers the question, *which journal influences which?* The third section presents the top 15 authors of the results shown. The individual results are categorized in 3 areas: authors, years and research areas. The top 15 categories ranked by number of publications are displayed. In general, a total of 38,532 papers were published by the 8 selected journals, 276,487 studies were found to cite the selected journals, and the total amount of cites gathered by the journals is 765,073 cites. Taking in count the search method and the journals selected, in the category of authors, the largest amount of citations was exhibited by ZS Xu, W Pedrycz, and F Herrera. The results shown in this study subscribe to an in-depth analysis of the top influencers in Fuzzy research. Future research is needed, firstly expand the number of journals to obtain a better approach to the influencers of each category, secondly include more categories to get a bigger picture of the data retrieved and with that a closer look to the evolution of Fuzzy research.

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