

A Bibliometric Analysis of the First Thirty Years of the International Journal of Intelligent Systems

José M. Merigó

Dept. Management
Control and Information
Systems, University of
Chile, Santiago, Chile
Email:
jmerigo@fen.uchile.cl

Fabio Blanco-Mesa

Dept. Business
Administration, Antonio
Nariño University, Tunja,
Colombia
Email:
fabio.blanco@uan.edu.co

Anna M. Gil-Lafuente

Dept. Business
Administration,
University of Barcelona,
Av. Diagonal 690, 08034
Barcelona, Spain
Email: amgil@ub.edu

Ronald R. Yager

Machine Intelligence
Institute, Iona College,
New Rochelle, NY
10801, USA
Email: yager@panix.com

Abstract—The International Journal of Intelligent Systems was created on 1986. Today, the journal has become thirty years old. In order to celebrate this anniversary, this study develops a bibliometric review of all the papers published in the journal between 1986 and 2015. The results are mainly based on the Web of Science Core Collection that classifies the bibliographic material by using several indicators including the total number of publications and citations, the *h*-index, the cites per paper and the citing articles. Moreover, the work also uses the VOS viewer software for visualizing the main results through bibliographic coupling and co-citation. The results show a general overview of the leading trends that have influenced the journal in terms of highly cited papers, authors, journals, universities and countries.

Keywords—*bibliometrics; International Journal of Intelligent Systems; Web of Science; VOS viewer*

I. INTRODUCTION

The International Journal of Intelligent Systems (IJIS) is a leading journal in the field of computer science and artificial intelligence with a focus on the theories based on intelligent systems construction. It was created by the current editor-in-chief, Ronald R. Yager in 1986. Throughout time, the journal has grown significantly and today is a main reference worldwide [1]. It is included in the Journal Citation Reports of the Web of Science Core Collection, which only indexes those journals that are recognized with the highest quality. Currently, it is a monthly journal and it is published by John Wiley & Sons international publisher.

Bibliometrics is a research field that studies the bibliographic material quantitatively [2]. It is very useful to analyze a research area and identify its leading trends. Bibliometrics can be developed in a wide range of contexts including the analysis of a research topic [3-4], journals [5-6], institutions [7] and countries [8]. There are several bibliometric studies close to the scope of IJIS including computational intelligence [9], fuzzy sets and systems [1], aggregation operators [10], intuitionistic fuzzy sets [11], linguistic decision making [12], grey systems [13] and ant colony optimization [14].

In 2016, IJIS celebrates its 30th anniversary. Motivated by this, the aim of this paper is to develop a bibliometric overview of the journal between 1986 and 2015. By doing so, we can see who is leading the journal and the main trends that have influenced more. The analysis considers a wide range of issues including the publication and citation structure of the journal, the most cited papers, the most influential authors, institutions and countries, and the citing articles. Moreover, the study also uses the VOS viewer software [15] to visualize the leading trends in the journal through bibliographic coupling [16] and co-citation analysis [17].

The rest of the paper is structured as follows. Section 2 briefly reviews the bibliometric methods used in the analysis. Section 3 presents the publication and citation structure of the journal. Section 4 maps the documents published in the journal by using the VOS viewer software. Section 5 summarizes the main findings and conclusions of the paper.

II. BIBLIOMETRIC METHODS

There are a wide range of methodologies that can be implemented when developing a bibliometric review. This study focuses on a general overview that presents different indicators so each reader can get its own understanding of the bibliometric data [18]. The main reason for this is that there is no single method that everybody agrees as the method to be used to evaluate research. Especially, this is clear for the comparison between productivity and influence that can be measured with the number of publications and citations, respectively.

To provide a complete picture of the data, the work uses the total number of publications and citations, the citations per paper, the *h*-index [19-20], the citing articles and citation thresholds [21]. The citing articles are those that cite the material considered in the analysis. The citation thresholds considered in the study analyze the number of papers that are above a specific number of citations.

The work uses the Web of Science (WoS) database that is currently owned by Thomson & Reuters. Particularly, we use the WoS Core Collection that indexes the documents that are

usually recognized with the highest quality. WoS currently indexes more than 50 million documents.

The search process uses the name of the journal “International Journal of Intelligent Systems” with the search option “Publication Name”. The search considers all the documents published in the journal between 1986 and 2015. Note that WoS only includes the journal since 1987. Therefore, for 1986 we develop a manual search through the Cited Reference Search tool and by looking to the documents available in 1986 in the webpage of the journal. The search process found 1602 documents published in the journal during the first thirty years. Currently, IJIS has received 16865 citations and has an *h*-index of 54. That is, of the 1602 documents, 54 have received 54 or more citations [22]. Note that the search process was carried out in November 2015 when all the documents were available in WoS.

III. RESULTS

A. Publication and citation evolution of IJIS

IJIS started publishing papers in 1986. At that time, it was a quarterly journal. In the nineties it increased from five issues in 1990, to seven issues in 1991, eight issues in 1992, nine in 1993, and finally in 1994 it consolidated as a monthly journal.

TABLE I. ANNUAL CITATION STRUCTURE OF IJIS

	≥50	≥20	≥10	≥1	TP	Total Cit	TC
1986	1	6	6	15	19	276	-
1987	-	2	4	10	13	133	2
1988	-	1	3	15	21	98	18
1989	1	2	4	16	20	175	19
1990	-	2	4	17	24	216	26
1991	3	6	14	31	37	550	52
1992	3	6	12	33	45	436	70
1993	4	10	16	38	43	879	76
1994	2	6	14	42	55	435	130
1995	2	6	14	40	47	436	153
1996	3	7	14	40	50	921	190
1997	1	4	11	43	50	568	203
1998	3	10	15	55	63	611	215
1999	2	14	18	50	64	670	244
2000	1	12	22	53	62	597	308
2001	7	15	30	62	78	1341	393
2002	3	13	23	57	65	1027	384
2003	8	16	28	67	73	1521	506
2004	2	8	16	61	76	637	483
2005	2	5	18	56	67	792	609
2006	1	9	21	54	68	669	743
2007	1	8	21	56	65	554	977
2008	4	9	16	55	66	692	1105
2009	2	9	15	57	65	715	1247
2010	4	9	19	51	68	899	1169
2011	2	4	6	50	63	416	1349
2012	-	3	9	41	53	291	1313
2013	-	1	5	42	65	194	1652
2014	-	1	1	30	58	102	1926
2015	-	-	-	10	59	14	1305
Total	62	204	399	1247	1602	16865	16865
Percentage	3,87%	12,73%	24,91%	77,84%	100%		

Source: Own elaboration based on WoS. ≥: it is an accumulated value; TP: Total number of papers in each year; Total Cit: Number of citations that the papers in each year have received; TC: Total citations received in that year.

Due to this, the first years saw an important increase in the annual number of documents published in the journal. Table I presents the citations that the documents published in each year have received in WoS. Note that the citation thresholds indicate the number of papers published in a specific year that have surpassed a number of citations.

Another interesting issue regarding citations is to analyze the most cited papers published in the journal. Table II presents the 10 most cited papers.

TABLE II. MOST CITED PAPERS PUBLISHED IN IJIS

R	Authors	Reference	TC	YP	C/Y
1	Yager, RR	[23]	438	1996	23,05
2	Xu, ZS; Da, QL	[24]	360	2003	30,00
3	Xu, ZS	[25]	267	2005	26,70
4	Torra, V	[26]	267	1997	14,83
5	Torra, V	[27]	246	2010	49,20
6	Delgado, M; Verdegay, JL; Vila, MA	[28]	225	1993	10,23
7	Yao, YY	[29]	199	2001	14,21
8	Xu, ZS; Da, QL	[30]	197	2002	15,15
9	Yao, X	[31]	168	1993	7,64
10	Zhao, H; Xu, ZS; Ni, MF; Liu, SS	[32]	157	2010	31,40

Source: Own elaboration based on WoS. TC: Total citations; YP: Year published; C/Y: Citations per year.

IJIS has received 16865 citations during these 30 years. Through WoS, we can analyze those papers that cite the journal through the “citing articles” link available in the citation report section. Table III presents those articles that have given citations to IJIS classified by journals, institutions and authors.

TABLE III. IJIS CITING ARTICLES

R	Journals	TP	Universities	TP	Authors	TP
1	ISC	448	U Granada	457	Xu ZS	184
2	IJIS	427	CNRS	209	Yager RR	166
3	FSS	396	Southeast U China	170	Herrera F	159
4	ESA	285	Iona College	163	Merigó JM	107
5	IEEETFS	266	U Jaen	159	Herrera-Viedma	101
6	IJAR	227	Polish Acad Sci	145	Martinez L	76
7	KBS	220	Ghent U	139	Torra V	71
8	IJUFKS	188	Southwest Jiaotong U	118	Ma ZM	66
9	JIFS	176	Tsinghua U	111	Kacprzyk J	66
10	SCO	149	Xi an Jiaotong U	106	Xu Y	65
11	ASC	140	U Barcelona	102	Prade H	65
12	EJOR	100	City U Hong Kong	97	Dubois D	64
13	IJCIS	81	CSIC	93	Montero J	62
14	IJGS	79	Northeastern U China	92	Wei GW	61
15	TSMCB	79	U Manchester	85	Liu J	61
16	ARIN	63	U Paul Sab Toulouse III	83	Pedrycz W	55
17	CIE	62	Chinese Acad Sci	83	Bustince H	55
18	TKDE	61	Sichuan U	81	Liu XW	54
19	FIN	60	Shanghai Jiao Tong U	79	Chen XH	54
20	FAIA	58	PLA U Sci Tech	79	Ruan D	52

Source: Own elaboration based on WoS. TP: Total publications; ISC: Information Sciences; IJIS: Int. J. Intelligent Systems; FSS: Fuzzy Sets and Systems; ESA: Expert Systems with Applications; IEEETFS: IEEE Trans. Fuzzy Systems; IJAR: Int. J. Approximate Reasoning; KBS: Knowledge Based Systems; IJUFKS: Int. J. Uncertainty Fuzziness and Knowledge Based Systems; JIFS: J. Intelligent & Fuzzy Systems; SCO: Soft Computing; ASC: Applied Soft Computing; EJOR: European J. Operational Research; IJCIS: Int. J. Computational Intelligence Systems; IJGS: Int. J. General Systems; TSMCB: IEEE Trans. Systems Man and Cybernetics Part B Cybernetics; ARIN: Artificial Intelligence; CIE: Computers Industrial Engineering; TKDE: IEEE Trans. Knowledge and Data Engineering; FIN: Fundamenta Informaticae; FAIA: Frontier in Artificial Intelligence and Applications; CNRS: National Research Council – France; CSIC: National Research Council – Spain.

B. Leading Authors, Universities and Countries in IJIS

Many important contributions have been published in the journal by a wide range of authors, institutions and countries. In this section, let us focus on those that have led the journal. For doing so, first, let us analyse the most productive and influential authors. Table IV presents the 20 most influential authors in the journal with a minimum publication level of five papers. Thus, the ranking is according to citations but only considering those authors that at least have published five documents in IJIS.

TABLE IV. MOST PRODUCTIVE AND INFLUENTIAL AUTHORS IN IJIS

R	Name	Country	IJIS				
			TC	TP	TC/TP	H T50	
1	Xu ZS	CHN	1466	25	58,64	14	6
2	Yager RR	USA	1168	37	31,57	18	3
3	Herrera F	ESP	830	20	41,5	14	6
4	Torra V	SWE	775	24	32,29	8	3
5	Vila MA	ESP	550	17	32,35	9	2
6	Prade H	FRA	509	26	19,58	12	2
7	Dubois D	FRA	485	17	28,53	12	2
8	Herrera-Viedma E	ESP	462	11	42	7	5
9	Verdegay JL	ESP	428	9	47,56	6	2
10	Delgado M	ESP	421	18	23,39	6	2
11	Chiclana F	UK	418	8	52,25	7	4
12	Ruan D	BEL	363	19	19,11	11	1
13	Lozano M	ESP	267	6	44,5	5	1
14	Pedrycz W	CAN	224	18	12,44	8	-
15	Kacprzyk J	POL	191	8	23,88	6	1
16	Smets P	BEL	181	5	36,2	5	2
17	Kahraman C	TUR	179	8	22,38	6	1
18	Merigó JM	CHL	177	5	35,4	3	2
19	Pasi G	ITA	163	10	16,3	6	2
20	Mitchell HB	ISR	158	10	15,8	7	-

Source: Own elaboration based on WoS. TC: Total Citations; TP: Total Publications; TC/TP: Cites per paper; H: *h*-index; T50 = Number of papers among the 50 most cited in the journal.

Zeshui Xu is the author that has received the highest influence based on his papers published in the journal. Yager appears in the second position although he is the most productive author in the journal. It is also worth noting that Xu and Francisco Herrera have published six papers among the 50 most cited in the journal. Note that some other very highly cited researchers have also influenced significantly the journal including Henri Prade, Didier Dubois, Enrique Herrera-Viedma and Witold Pedrycz.

Many institutions have a lot of influence in IJIS. Usually, the leading institutions are those where the leading authors work. However, sometimes, there are some institutions that include a wide range of leading authors making them more influential. Table V shows the 20 most productive institutions in IJIS. Note that the table also considers the citations, the citations per paper and the *h*-index.

Another interesting issue to consider is to classify the authors and institutions by countries. Thus, we can see the regions where IJIS is more influential. For doing this, Table VI presents the 20 most productive countries in the journals. The countries are ranked by total productivity although some other indicators are considered including the citations and the productivity and influence per person.

TABLE V. 20 MOST PRODUCTIVE INSTITUTIONS IN IJIS

R	Universities	Country	TP	H	TC	TC/TP
1	U Granada	ESP	91	22	1814	19,93
2	CNRS	FRA	44	14	631	14,34
3	Iona College	USA	40	16	1088	27,20
6	CSIC	ESP	31	10	570	18,39
4	Polish Academy of Sciences	POL	31	12	422	13,61
5	U Paul Sabatier Toulouse III	FRA	29	13	420	14,48
7	U Texas El Paso	USA	24	6	95	3,96
8	U Polytechnic Madrid	ESP	22	8	209	9,50
9	Ghent U	BEL	22	9	201	9,14
10	Southeast U	CHN	21	13	1303	62,05
11	Chinese U Hong Kong	CHN	18	7	155	8,61
12	New Mexico State U	USA	17	6	191	11,24
13	U South Florida	USA	17	5	60	3,53
14	U Alberta	CAN	16	7	191	11,94
15	U Bristol	UK	16	6	128	8,00
16	National Central U	TWN	16	5	80	5,00
17	U Jaen	ESP	15	8	320	21,33
18	Belgium Centre Nuclear Research	BEL	15	9	266	17,73
19	CNR	ITA	15	7	221	14,73
20	U Salerno	ITA	15	5	107	7,13

Source: Own elaboration based on WoS.

Another interesting issue to consider is to classify the authors and institutions by countries. Thus, we can see the regions where IJIS is more influential. For doing this, Table VI presents the 20 most productive countries in the journals. The countries are ranked by total productivity although some other indicators are considered including the citations and the productivity and influence per person.

TABLE VI. 20 MOST PRODUCTIVE COUNTRIES IN IJIS

R	Countries	TP	H	TC	TC/TP	TP/Pop	TC/Pop
1	USA	422	29	3589	8,50	1,32	11,26
2	Spain	238	33	3855	16,20	5,13	83,07
3	Peoples R China	178	26	2755	15,48	0,13	2,02
4	Italy	110	17	1066	9,69	1,79	17,38
5	France	106	18	1110	10,47	1,60	16,77
6	UK	98	16	1105	11,28	1,52	17,13
7	Canada	70	16	831	11,87	1,97	23,38
8	Taiwan	61	11	428	7,02	2,60	18,26
9	Japan	60	9	376	6,27	0,47	2,96
10	Belgium	59	16	805	13,64	5,26	71,71
11	Poland	51	16	1040	20,39	1,34	27,37
12	Germany	44	11	309	7,02	0,54	3,82
13	Australia	41	12	535	13,05	1,75	22,77
14	Israel	30	8	214	7,13	3,65	26,05
15	South Korea	28	9	239	8,54	0,56	4,74
16	India	28	6	119	4,25	0,02	0,09
17	Greece	28	6	83	2,96	2,56	7,57
18	Turkey	26	9	307	11,81	0,34	4,04
19	Netherlands	25	7	128	5,12	1,48	7,59
20	Sweden	17	6	130	7,65	1,75	13,42

Source: Own elaboration based on WoS. TP/Pop: Number of papers per million inhabitants; TC/Pop: Number of citations per million inhabitants.

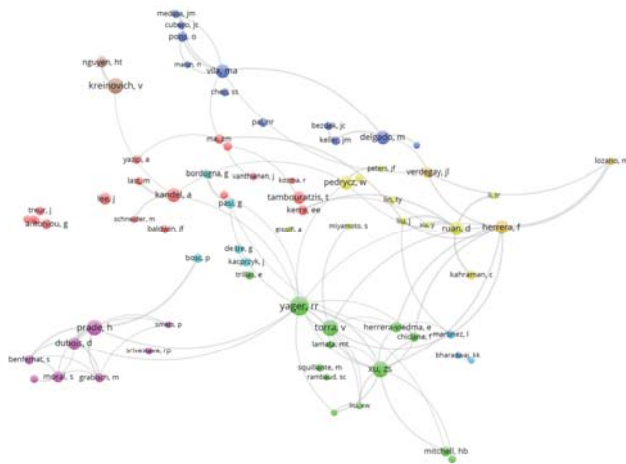
The USA, Spain and China are the leading countries in IJIS. It is worth noting the case of Spain because it is a much smaller country compared to the other two. These can be proved by looking to the per capita results where Spain obtains a very remarkable rate. Note that Belgium also obtains similar results than Spain. However, since it is four times smaller, it does not get a significant position at the top of the list.

IV. MAPPING IJIS WITH THE VOS VIEWER SOFTWARE

In order to get a more complete picture of the leading trends occurring in IJIS, we use the VOS viewer software [15] that visualizes the bibliographic material through bibliographic coupling [16] and co-citation analysis [17]. Bibliographic coupling occurs when two documents published in IJIS cites the same third document. Co-citation occurs when two documents receive a citation by a third document that has been published in IJIS. Therefore, bibliographic coupling represents the highest productivity in the journal and how this research is connected. And co-citation shows the most cited research in the journal and its connections.

In order to carry out the graphical analysis, first, let us focus on bibliographic coupling. Figure 1 presents the bibliographic coupling of the most productive authors in IJIS.

Fig. 1. Bibliographic coupling of authors that publish in IJIS



As we can see, Yager is at the core of the graph with the most significant connections. Herrera, Xu, Dubois, Prade and Kandel also have a significant position.

Now, let us focus on co-citation analysis. A first interesting issue here is to consider the most cited papers in IJIS and how they are connected with other papers. Figure 2 presents the co-citation of documents.

The most cited paper in the journal is the seminal paper of Zadeh about “Fuzzy sets” that was published in 1965 in Information and Control [33]. This paper is among the 50 most cited papers of all time in all sciences and the most cited paper in computer science [1]. Very close to this paper appears the seminal paper of Yager about the OWA operator [34-35]. It is also worth noting that several books are highly cited in the journal [36]. Zadeh and Yager are the authors with the highest number of papers in the graph.

A further interesting issue is to consider the co-citation of authors. That is, the authors that have received the highest number of citations in the journal and how their profile is connected to other authors. Figure 3 presents the leading co-cited authors of IJIS.

Fig. 2. Co-citation of documents cited in IJIS

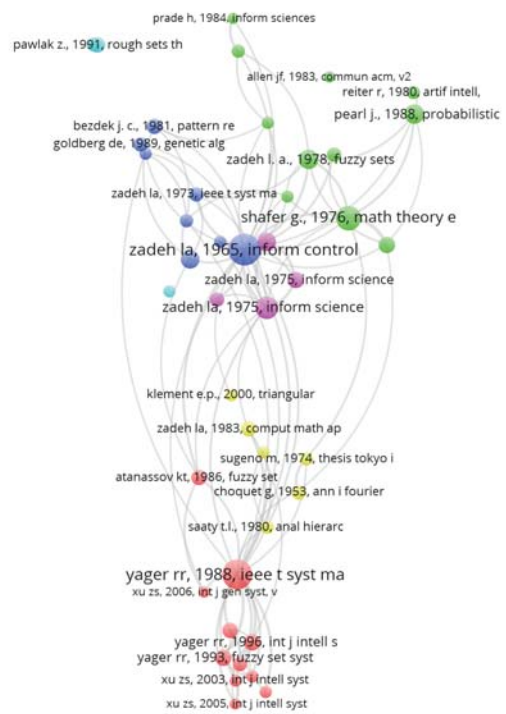
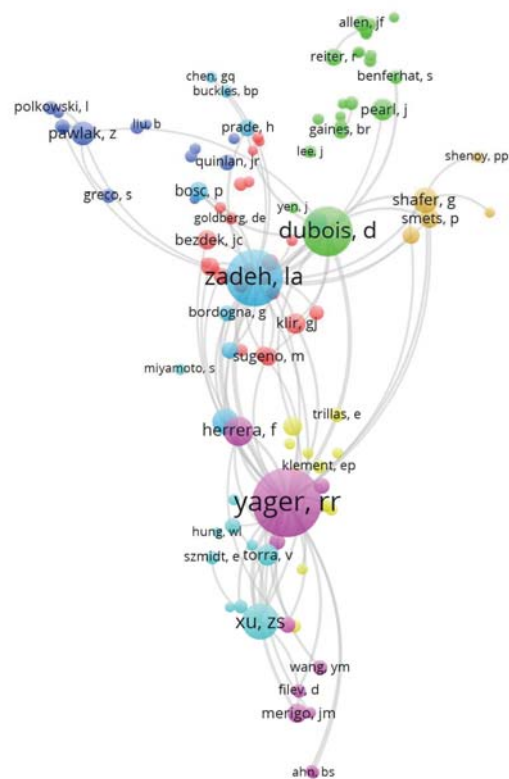


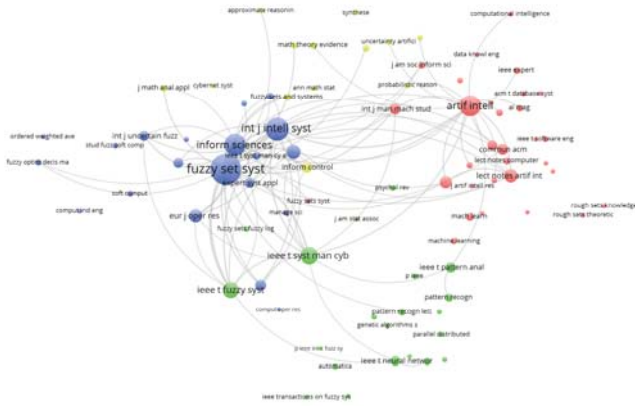
Fig. 3. Co-citation of authors cited in the journal



Yager is the most cited author in the journal closely followed by Zadeh. These two authors clearly represent the core of this journal. However, some other authors also reach a significant position including Dubois, Xu and Herrera. Most of these authors did appear in Table IV with the exception of some highly cited authors through their books such as Glenn Shafer, Judea Pearl and George J. Klir.

Next, let us analyze the co-citation of journals in IJIS. That is, those journals that have received the highest number of citations in the journal. Figure 4 presents the results.

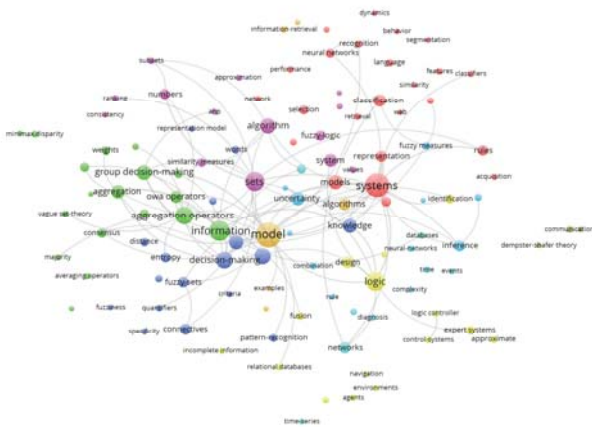
Fig. 4. Co-citation of journals cited in IJIS



Fuzzy Sets and Systems is the most cited journal in IJIS, followed by IJIS itself. Close to them appear Information Sciences, Artificial Intelligence and the IEEE Transactions on Systems, Man and Cybernetics that now is divided in three journals. Most of the journals are from the computer science area although some other areas close to this field also appear including engineering, mathematics and operations research.

Finally, let us develop a keyword analysis of the journal in order to identify the most frequently used keywords in the journal. Figure 5 presents the leading keywords of IJIS.

Fig. 5. Co-occurrence of keywords in IJIS



As we can see, some keywords are quite common in many journals such as preface, special issue, case, review and so on.

However, there are also some groups of keywords that clearly show the profile of the journal. First, at the bottom of the graph we see several keywords about decision making, aggregation operators and OWA operators. At the right-bottom side of the graph we identify several keywords about fuzzy sets and systems. These two groups represent the most significant ones although there are some other ones about probability, knowledge and more generally, on computational intelligence.

V. CONCLUSIONS

Now, the International Journal of Intelligent Systems is thirty years old and many research contributions have been published during this time. This study presents a bibliometric review of the journal during this period of time in order to identify the leading trends that have occurred in the journal. The analysis has been carried out by searching for the bibliographic material in WoS database. Several bibliometric indicators have been considered including the total number of publications and citations, the *h*-index, the cites per paper, citation thresholds and citing articles. The results indicate that IJIS is a leading journal in the computer science field with a special focus on intelligent systems construction that include fuzzy systems, aggregation operators, decision making and computational intelligence in general. The journal is strongly connected to other leading journals such as Fuzzy Sets and Systems, Information Sciences, IEEE Transactions on Systems, Man and Cybernetics (now divided in three parts) and the IEEE Transactions on Fuzzy Systems. Zeshui Xu and Ronald R. Yager are the most productive and influential authors in the journal in terms of papers published and citations that these papers have received. The University of Granada is the leading institution according to these indicators. From these results, three countries show the most significant presence in the journal: China, USA and Spain.

The article also develops a graphical analysis of the publication and citation structure of the journal in order to map the leading issues in the journal and see how they are connected. For doing so, the paper has studied bibliographic coupling and co-citation. The graphical results are quite consistent with the results seen in the tables although it is worth noting that the most cited authors in the journal are Lotfi A. Zadeh and Ronald R. Yager. Their seminal papers are the leading documents on fuzzy sets [33] and OWA operators [35,37], respectively.

This paper provides an overview of the leading trends in the journal over the last thirty years. This approach is useful to get a general overview. However, it is worth noting some limitations. First, the results may change throughout time and many new issues may appear and condition the journal in the future. Second, we follow the methodology that WoS uses for classifying bibliographic material. But this approach has limitations that also affect this study. Finally, it is worth mentioning that the article measures the bibliographic material. But many times productivity and influence may be conditioned by popularity and other related factors. Therefore, sometimes very good research may not appear highly rated. In this

context, the paper aims to identify the leading trends and be informative, but obviously, many exceptional cases may appear in the analysis.

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