COMPUTER SCIENCE RESEARCH IN ARTIFICIAL INTELLIGENCE

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Abstract—This paper presents a bibliometric overview of the research carried out between 1990 and 2014 in computer science with a focus on artificial intelligence. The work analyses all the journals available in Web of Science during this period and presents their publication and citation results. The study also considers the most cited articles in this area during the last twenty-five years. IEEE Journals obtain the most remarkable results publishing more than half of the most cited papers.

Index Terms— Bibliometrics, Web of Science, journals, citations.

I. INTRODUCTION

Artificial intelligence is a research area that studies how systems can think artificially or in related ways. It represents an important part of computer science. In the Web of Science (WoS) database there is one specific research category of the

251 categories strictly dedicated to this field, “Computer Science, Artificial Intelligence”. This area is becoming very popular due to the strong development of computers and technology. In order to assess the publications in this field, we can use bibliometrics which analyses the bibliographic material quantitatively [4]. In the literature, there are many articles that have developed a bibliometric analysis of a research field including management [18], economics [3,5], innovation, [8], fuzzy research [16], aggregation systems [7,23], grey systems [22] and computational intelligence [21]. Focusing on computer science, there are also some bibliometric studies. For example, Guan and Ma [12] developed a comparative analysis of the research performance, Tsai [20] studied the citation impact of computer science journals, and Feitelson and Yovel [9] analysed authors through the CiteSeer data. Some other studies have analysed computer science in specific regions including India [19], Brazil [15], Spain [14], Argentina [11]and Malaysia [2].

The aim of this paper is to analyse the artificial intelligence section of computer science. For doing so, we follow the WoS database which classifies a group of journals in this category. Thus, we study all the articles published in these journals between 1990 and 2014. Note that some journals may partially publish material in this discipline. However, our focus is on analyse the journals strictly dedicated to this area and identifying the most cited papers.

This paper is organized as follows. Section II briefly reviews the bibliometric methodology used in the paper. Section III, presents the results

and Section IV summarizes the main findings and conclusions of the paper.

II. METHODS

WoS is usually regarded as the most influential database for scientific research. Usually, those journals included here are recognized of those with the highest quality. WoS contains more than 15.000 journals and 50.000.000 documents. Currently, it continues growing, especially with the newest expansion produced by the creation of the Emerging Sources Citation Index that will include journals of high quality that need a period of evaluation before receiving an impact factor although already available in the database. The scientific material is divided in 251 research categories. Computer science encompasses seven of these categories and one of them is focused on Artificial Intelligence.

In order to analyze the data, this study uses several bibliometric indicators [17]. Particularly, we use the total number of publications and citations, the h-index [13], the cites per paper, and the number of papers among the thirty most cited in the field between 1990 and 2014. Note that the h-index is a modern index that tries to integrate publications with citations. In summary, if a set of papers have an h-index of X, it means that X papers of the total set, have received X or more citations. In general, this index works quite well although it is not able to consider some exceptional situations. For example, if an author has five papers and two of them have one thousand citations and the other three zero, his h-index is two. However, if another author have five papers with five citations each, he has an h-index of five. Here, the second author gets a better result although it is clear that the first one is more influential. Due to this, some other measures have appeared in the literature including the g-index [6] and the hg-index [1].

The search process looks for the documents published in the WoS category of Computer Science, Artificial Intelligence between 1990 and 2014. Only articles, reviews, letters and notes are considered. The main reason is that the other types of documents are usually not scientific material. All the journals are ranked according to the total number of citations. However, WoS does not distinguish between the sources that give the citations. From a general perspective, this should not bring important deviations but it is worth

Table 1. Journals in Computer Science: Artificial Intelligence

R	Name	TC	TP	H	TC/TP	Y	V	T30
1	IEEETrans.PatternAnalysisandMachineIntelligence	276.428	3.985	222	69,37	1990	12	9
2	IEEETrans.ImageProcessing	162.993	4.894	167	33,30	1992	1	3
3	IEEETrans.NeuralNetworksandLearningSystems	129.598	3.705	137	34,98	1991	2	3
4	PatternRecognition	115.209	5.630	119	20,46	1990	23	-
5	Int.J.ComputerVision	97.525	1.639	138	59,50	1990	4	3
6	NeuralComputation	88.807	2.405	129	36,93	1992	4	2
7	ExpertSystemswithApplications	85.240	9.165	74	9,30	1991	2	-
8	NeuralNetworks	75.163	2.981	113	25,21	1990	3	1
9	MachineLearning	72.098	1.19	105	60,13	1990	5	3

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10	IEEETrans.FuzzySystems	66.695	1.722	116	38,73	1994	2	-
11	PatternRecognitionLetters	64.250	4.860	85	13,22	1990	11	1
12	ArtificialIntelligence	63.072	1.979	113	31,87	1990	41	-
13	ChemometricsandIntelligentLaboratorySystems	52.604	2.836	94	18,55	1990	7	-
14	Neurocomputing	49.704	6.436	65	7,72	1992	4	-
15	ComputerVisionandImageUnderstanding	48.737	1.958	93	24,89	1991	53	1
16	IEEETrans.KnowledgeandDataEngineering	46.604	2.650	91	17,59	1992	4	-
17	IEEETrans.onEvolutionaryComputation	45.936	786	95	58,44	1999	3	2
18	ImageandVisionComputing	39.830	2.354	78	16,92	1990	8	-
19	J.MachineLearningResearch	36.363	1.220	80	29,81	2001	1	1
20	DecisionSupportSystems	33.782	2.493	68	13,55	1991	7	-
21	RoboticsandAutonomousSystems	23.919	1.914	60	12,50	1994	13	-
22	J.ArtificialIntelligenceResearch	19.434	777	62	25,01	1995	3	-
23	EngineeringApplicationsofArtificialIntelligence	18.502	2.189	47	8,45	1992	5	-
24	EvolutionaryComputation	18.288	502	58	36,43	1993	1	-
25	Int.J.ApproximateReasoning	17.234	1.343	53	12,83	1993	8	-
26	ArtificialIntelligenceinMedicine	15.890	1.189	48	13,36	1992	4	-
27	DataMiningandKnowledgeDiscovery	15.833	497	55	31,86	1997	1	1
28	Knowledge-BasedSystems	15.608	2.044	41	7,64	1991	4	-
29	Mechatronics	15.429	1.721	43	8,97	1992	2	-
30	AutonomousRobots	15.093	806	60	18,73	1996	3	-
31	Int.J.IntelligentSystems	14.781	1.470	51	10,06	1990	5	-
32	Data&KnowledgeEngineering	14.347	1.288	51	11,14	1994	12	-
33	Network-ComputationinNeuralSystems	14.145	603	59	23,46	1990	1	-
34	J.IntelligentManufacturing	11.990	1.489	41	8,05	1990	1	-
35	IEEEIntelligentSystems	11.496	1.416	49	8,12	2001	16	-
36	AIMagazine	10.668	969	49	11,01	1990	11	-
37	ComputationalLinguistics	10.492	741	48	14,16	1995	21	-
38	J.MathematicalImagingandVision	10.407	888	44	11,72	1996	6	-
39	SoftComputing	9.525	1.588	35	6,00	2002	7	-
40	J.Intelligent&RoboticSystems	9.495	1.782	31	5,33	1990	3	-
41	Int.J.UncertaintyFuzzinessandKnowledgeBasedSystems	9.363	1.028	42	9,11	1995	3	-
42	ComputerSpeechandLanguage	8.260	612	40	13,50	1994	8	-
43	ArtificialIntelligenceReview	8.170	713	37	11,46	1990	4	-
44	Int.J.PatternRecognitionandArtificialIntelligence	7.757	1.439	33	5,39	1995	9	-

45	NeuralProcessingLetters	7.490	802	32	9,34	1994	1	-
46	KnowledgeEngineeringReview	7.448	459	35	16,23	1994	9	-
47	AppliedIntelligence	7.074	1.011	34	7,00	1993	3	-
48	NeuralComputing&Applications	7.056	1.990	28	3,55	1995	3	-
49	ArtificialLife	6.442	415	36	15,52	1998	4	-
50	AppliedArtificialIntelligence	6.336	912	37	6,95	1991	5	-
51	AnnalsofMathematicsandArtificialIntelligence	6.147	874	34	7,03	1995	13	-
52	J.AutomatedReasoning	5.644	692	34	8,16	1993	10	-
53	AdvancedEngineeringInformatics	5.413	539	31	10,04	2002	16	-
54	Int.J.NeuralSystems	5.259	562	31	9,36	1992	3	-
55	SIAMJ.ImagingSciences	5.258	398	26	13,21	2008	1	-
56	AIEdam-ArtificialIntell.Engin.DesignAnalysisManuf.	5.119	664	30	7,71	1993	7	-
57	AdaptiveBehavior	5.051	494	36	10,22	1994	3	-
58	AutonomousAgentsandMulti-AgentSystems	5.026	398	31	12,63	2000	3	-
59	PatternAnalysisandApplications	4.699	569	32	8,26	1998	1	-
60	J.IntelligentInformationSystems	4.590	537	29	8,55	1998	10	-
61	ComputationalIntelligence	4.504	596	31	7,56	1995	11	-
62	AICommunications	4.291	527	25	8,14	1994	7	-
63	J.WebSemantics	4.129	290	30	14,24	2005	3	-
64	InformationFusion	3.529	395	30	8,93	2006	7	-
65	Int.J.InformationTechnology&DecisionMaking	3.246	532	24	6,10	2004	3	-
66	J.Experimental&TheoreticalArtificialIntelligence	3.196	549	25	5,82	1993	5	-
67	J.Intelligent&FuzzySystems	3.151	1.303	21	2,42	1995	3	-
68	IEEEComputationalIntelligenceMagazine	3.068	260	25	11,80	2006	1	-
69	Int.J.SoftwareEngineeringandKnowledgeEngineering	2.979	963	23	3,09	1991	1	-
70	ExpertSystems	2.662	771	22	3,45	1994	11	-
71	MindsandMachines	2.601	523	22	4,97	1992	2	-
72	ConnectionScience	2.546	308	23	8,27	1998	10	-
73	Int.J.AppliedMathematicsandComputerScience	2.086	518	18	4,03	2003	13	-
74	Int.J.ComputationalIntelligenceSystems	1.690	592	18	2,85	2008	1	-
75	CognitiveSystemsResearch	1.644	289	17	5,69	2005	6	-
76	FuzzyOptimizationandDecisionMaking	1.464	193	20	7,59	2007	6	-
77	Int.J.ArtificialIntelligenceTools	1.285	557	14	2,31	2005	14	-
78	Int.J.DocumentAnalysisandRecognition	1.220	221	17	5,52	2006	8	-
79	IntelligentDataAnalysis	1.184	502	14	2,36	2005	9	-
80	Int.J.FuzzySystems	1.15	348	14	3,32	2007	9	-

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81ACMTrans.IntelligentSystemsandTechnology	4 1.108	259	7	4,28	2010	1	-
82Int.J.Bio-InspiredComputation	1.040	204	15	5,10	2009	1	-
83ComputingandInformatics	1.008	663	11	1,52	2001	20	-
84IntelligentAutomationandSoftComputing	992	768	13	1,29	1998	4	-
85ACMTrans.AutonomousandAdaptiveSystems	901	190	13	4,74	2006	1	-
86Int.J.MachineLearningandCybernetics	888	206	13	4,31	2011	2	-
87J.Multiple-ValuedLogicandSoftComputing	887	455	12	1,95	2004	10	-
88Int.J.SemanticWebandInformationSystems	857	127	13	6,75	2006	2	-
89J.Real-TimeImageProcessing	837	286	13	2,93	2006	1	-
90CognitiveComputation	808	280	13	2,89	2009	1	-
91IEEETrans.AutonomousMentalDevelopment	803	154	13	5,21	2009	1	-
92AdvancesinElectricalandComputerEngineering	766	481	9	1,59	2007	7	-
93NeuralNetworkWorld	763	429	10	1,78	2005	15	-
94GeneticProgrammingandEvolvableMachines	760	160	13	4,75	2007	8	-
95IET ComputerVision	704	293	11	2,40	2007	1	-
96TurkishJ.ElectricalEngineeringandComputerSciences	618	589	8	1,05	2008	16	-
97IEEETrans.ComputationalIntelligenceandAIinGames	613	162	12	3,78	2009	1	-
98J.AmbientIntelligenceandSmartEnvironments	569	238	11	2,39	2009	1	-
99NaturalComputing	527	296	9	1,78	2010	9	-
100WileyInterdis.Reviews-DataMiningKnowledgeDisc.	496	137	11	3,62	2011	1	-
101J.AppliedLogic	310	167	9	1,86	2009	7	-
102SwarmIntelligence	226	67	8	3,37	2010	4	-
103NaturalLanguageEngineering	172	134	7	1,28	2009	15	-
104TraitementduSignal	61	210	3	0,29	2007	24	-
105MemeticComputing	61	74	4	0,82	2012	4	-
106IETBiometrics	59	79	4	0,75	2012	1	-

Abbreviations: R = Ranking according to TC; TC = Total citations; TP = Total papers; TC/TP = Average citations per paper; Y= Year; V = Volume; IF = Impact factor; IF5 = 5-year impact factor; T50 = Number of papers among the 50 most cited of the category; T200 = Number of papers among the 200 most cited in all fields of computer science since 1990; T200 < 1990 = Number of papers among the 200 most cited in all fields of computer science before 1990; GR = Global ranking considering all the computer science journals.

III. RESULTS

Currently, there are 106 journals in WoS in the category of Computer Science, Artificial Intelligence. However, note that this number is constantly changing, especially now with the introduction of the Emerging Sources Citation Index. Table 1 presents the journals ranked according to their number of citations obtained between 1990 and 2014.

The IEEE Transactions Journals obtain the most remarkable results [10]. Particularly, the IEEE Transactions

on Pattern Analysis and Machine Intelligence, the IEEE Transaction on Image Processing and the IEEE Transactions on Neural Networks and Learning Systems, obtain the first three positions. Note that some other journals obtain better results according to other indicators including the International Journal of Computer Vision, Machine Learning and the IEEE Transactions on Evolutionary Computation.

Next, let us look into the most cited papers in this field over the last twenty-five years. Table 2 presents the thirty most cited papers in Computer Science, Artificial Intelligence

Table 2. Most cited papers in Computer Science: Artificial Intelligence

1	IJCV	10356	Distinctiveimagefeaturesfromscale-invariant keypoints	Lowe, DG	2004
2	ML	7192	Randomforests	Breiman,L	2001
3	ML	6494	Support-VectorNetworks	Cortes,C;VapnikV	1995
4	TRECO	6035	Afastandelitistmultiobjectivegeneticalgorithm: NSGA-II	Deb,K;Pratap,A;Agarwal,S;et al.	2002
5	ML	5354	Baggingpredictors	Breiman,L	1996
6	TPA	4430	Amethodforregistrationof3-Dshapes	Besl,PJ; Mckay,ND	1992
7	DMKD	4262	AtutorialonSupportVectorMachinesforpattern recognition	Burges,CJC	1998
8	TPA	4251	Scale-SpaceandEdge-Detectionusinganisotropic diffusion	Perona,P; MalikJ	1990
9	TIP	4032	Imagequalityassessment:Fromerrorvisibilitytostructuralsimilarity	Wang,Z;Bovik,AC;Sheikh,HR;et al.	2004
10	TPA	3890	Eigenfacesvs.Fisherfaces:Recognitionusingclass specificlinearprojection	Belhumeur,PN;Hespanha,JP;Kriegman,DJ;etal.	1997
11	NC	3487	Aninformationmaximizationapproachtoblind separationandblinddeconvolution	Bell,AJ;Sejnowski,TJ	1995
12	TPA	3306	Normalizedcutsandimagesegmentation	Shi, JB; Malik,J	2000
13	TIP	3239	Activecontourswithoutedges	Chan, TF;Vese, LA	2001
14	TPA	2972	Meanshift:Arobustapproachtowardfeaturespaceanalysis	Comaniciu,D;Meer,P	2002
15	CVIU	2841	Activeshapemodels-Theirtrainingandapplication	Cootes,TF;TaylorCJ; CooperDH;etal.	1995
16	IJCV	2818	Robustreal-timefacedetection	Viola, P; Jones,MJ	2004
17	TPA	2700	Amodelofsaliency-basedvisualattentionforrapid sceneanalysis	Itti,L;Koch,C;Niebur,E;etal.	1998
18	TRECO	2585	Theparticleswarm-Explosion,stability,and convergenceinamultidimensionalcomplexspace	Clerc,M;Kennedy,J	2002
19	JMLR	2581	LatentDirichletallocation	Blei,DM;Ng,AY;Jordan,MI; et al.	2003
20	NC	2534	Nonlinearcomponentanalysisasakerneleigenvalue problem	Scholkopf,B;Smola,A;Muller,KR;etal.	1998
21	TNN	2407	Trainingfeedforwardnetworkswiththemarquardt algorithm	Hagan,MT;Menhaj,MB	1994
22	PRL	2396	AnintroductiontoROCanalysis	Fawcett, T	2006
23	TPA	2336	Aflexiblenewtechniqueforcameracalibration	Zhang,ZY	2000
24	TIP	2312	Securespreadspectrumwatermarkingformultimedia	Cox,IJ;Kilian,J;Leighton, FT;etal.	1997
25	TPA	2296	Multiresolutiongray-scaleandrotationinvariant textureclassificationwithlocalbinarypatterns	Ojala,T;Pietikainen,M;Maenpaa,T; etal.	2002
26	IJCV	2292	Colorindexing	Swain,MJ;Ballard,DH	1991
27	TPA	2265	Oncombiningclassifiers	Kittler,J;Hatef,M;Duin,RPW;et al.	1998
28	NN	2208			
29	TNN	2199			

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Independentcomponentanalysis:algorithmsandapplications			
			Fastandrobustfixed-pointalgorithmsforindependentcomponentanalysis
30	TNN	2120	Acomparisonofmethodsformulticlasssupportvector

Abbreviations: R = Rank; TC = Total citations; IJCV = Int. J. Computer Vision; ML = Machine Learning; TRECO = IEEE Trans. Evolutionary Computation; IEEE Trans. Pattern Analysis and Machine Intelligence; DMKD = Data Mining and Knowledge Discovery; TIP
= IEEE Trans. Image Processing; NC = Neural Computation; CVIU = Computer Vision and Image Understanding; JMLR = J. Machine Learning Research; TNN = IEEE Trans. Neural Networks; PRL = Pattern Recognition Letters.

The most cited article of the last twenty-five years is published in the International Journal of Computer Vision by Lowe and has received more than 10.000 citations. The IEEE Transactions on Pattern Analysis and Machine Intelligence has nine papers in the Top 30. All the papers in the list have received more than 2.000 citations.

IV. CONCLUSION

This study has presented an overview of the leading trends in the field of artificial intelligence in computer science. The results are based on WoS and clearly show the relevance of the IEEE journals as the leaders of the field. However, there are many other important journals in this area. Depending on the bibliometric indicator considered, some journals may obtain better results than others. This work has ranked the journals according to the total number of citations but it also presents other indicators in order to give a more general perspective of the characteristics of each journal. The current trend is that more journals are entering WoS, especially motivated by the strong growth of researchers worldwide that needs a higher supply of journals.

The paper has also considered the most cited papers in this area between 1990 and 2014. The IEEE Transactions on Pattern Analysis and Machine Intelligence is the most influential journal with nine papers in the Top 30 and is the most cited journal in the ranking.

In future research, we will look into other issues including leading authors, institutions and countries. Moreover, we will also consider other computer science categories including information systems, interdisciplinary applications and cybernetics.

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