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Application of Artificial Intelligence to Covid-19: A Scientometric Analysis of Global Publications during 2020-21

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The paper examines global 1142 research publications in the field of "Application of Artificial Intelligence to Covid-19" during 2020-21, using publication data indexed in Scopus database. It assesses and evaluates the research performance of this theme based on quantitative and qualitative indicators. 1142 global papers have cited 7673 times, articles involving 87 countries, 2089 organisations and 5069 authors. Global research comes from 542 different sources. Research has observed that the United States and India lead the world, accounting for 21.54% and 19.53%share in global publications and citations respectively. The study tracks key research organisations, authors, research areas and most significant keywords, cited papers, and productive sources. The study also presents a visual map of a collaborative network involving key countries, institutions, authors, and important keywords in this domain.

Keywords: *Covid-19, Artificial intelligence, Machine learning, Global publications, Scientometrics, Bibliometrics*

1 INTRODUCTION

Artificial intelligence (AI), a branch of computer science, aims to create a computer system that can think like a human being. Research in artificial intelligence is progressing very fast and people hope that its applications will change the society as profoundly as electricity [1].Over the years, AI has been adopted by major organisations and governments around the world as one of the key strategies for processing massive digital data generated in the information age: the "bib data" era [2]. Recognising the importance of AI, the United States Government issued a global call to artificial intelligence community to develop novel text and data-mining approaches to aid Covid-19 related research, in collaboration with research institutes and technical companies on 16 March 2020[3].

Machine learning (ML) is a subfield of AI and one of the newer technologies of AI [4],while deep learning is a sub-set of ML, which uses neural networks - one of

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the most elegant programming paradigms ever devised[5]. Over the years, a number of applications of AI have been developed in the medical and healthcare sector, which is used for the prediction, diagnosis, and treatment of diseases[6]. Artificial intelligence and machine learning are used to improve the accuracy of detection of infectious and non-infectious diseases[7]. Due to the integration of large digital data sources, the computing power to identify clinically significant patterns in the data through the use of efficient artificial intelligence and machine learning algorithms become a reality[8].

In this context, the present study aims to study Covid-19 related artificial intelligence research publications based on key biblio metric indicators, with a focus on: (i) distribution of global publications output by source and type, (ii) identification of most productive countries, (iii) publication distribution by broad subjects and significant keywords, (iv) identification of most productive organisations and authors and their collaborative linkages, (v) identification of the leading communication channels and (vi) analysis of the bibliographic characteristics of highly- cited papers in the subject.

11 LITERATURE REVIEW

In the two years, a large number of bibliometric studies have been conducted on assessment of global literature on Covid-19. Among such studies, Gupta, Dhawan, Ahmed and Mamdapur [9] examined 103,054 global records on Covid-19 and present a bibliometric profile of most influential countries, organisations, authors and journals and their collaborative linkages. They have also identified broad subject areas of research, most significant keywords and highly-cited papers related to Covid-19.

Few studies were also carried out in the domain pertaining to the applications of artificial intelligence in medical sector and Covid-19 in particular. Amongst such studies, Guo et al[10] performed a bibliometric analysis of global literature on healthcare related AI publications. Vaishya et al. [11]studied the role of AI as a key technology for analysing, preparing and preventing and fighting Covid-19 and identified seven major AI applications for Covid-19 pandemic. Islam et al. [12] performed a bibliometric analysis of the research trends, research-subfields, publication patterns, emerging topics and global collaborations in the field of AI on Covid-19. Al-Emran and Arpaci [13] conducted a bibliometric analysis on intelligent systems and Covid-19 with a focus on most used keywords, most cited articles and journals, most productive countries and institutions, most cited authors.

2 DATA AND METHODS

In the present study, the Scopus database was used to identify and download the relevant publication data using the following search strategy.

(((TITLE (“Covid 19” or “2019 novel coronavirus” or “coronavirus 2019” or “coronavirus disease 2019” or “2019-novel CoV” or “2019 ncov” orCovid 2019 orCovid19 OR “Corona virus 2019” or ncov-2019 or ncov2019 or “nCoV 2019”

or 2019-ncov orCovid-19 or "Severe acute respiratory syndrome coronavirus 2" or "SARS-CoV-2") or KEY ("COVID 19" OR "2019 novel coronavirus" OR "coronavirus 2019" OR "coronavirus disease 2019" OR "2019-novel CoV" OR "2019 ncov" OR covid 2019 OR covid19 OR "corona virus 2019" OR ncov-2019 OR ncov2019 OR "nCoV 2019" OR 2019-ncov OR covid-19 OR "Severe acute respiratory syndrome coronavirus 2" OR "SARS-CoV-2")) and (TITLE (Artificial intelligence or machine learning or deep learning) OR KEY (Artificial intelligence or machine learning or deep learning))) OR ((TITLE ("COVID 19" OR "2019 novel coronavirus" OR "coronavirus 2019" OR "coronavirus disease 2019" OR "2019-novel CoV" OR "2019 ncov" OR covid 2019 OR covid19 OR "corona virus 2019" OR ncov-2019 OR ncov2019 OR "nCoV 2019" OR 2019-ncov OR covid-19 OR "Severe acute respiratory syndrome coronavirus 2" OR "SARS-CoV-2") OR KEY ("COVID 19" OR "2019 novel coronavirus" OR "coronavirus 2019" OR "coronavirus disease 2019" OR "2019-novel CoV" OR "2019 ncov" OR covid 2019 OR covid19 OR "corona virus 2019" OR ncov-2019 OR ncov2019 OR "nCoV 2019" OR 2019-ncov OR covid-19 OR "Severe acute respiratory syndrome coronavirus 2" OR "SARS-CoV-2")) and (TITLE (Neural network or Supervised Learningor Unsupervised Learningor Reinforced Learning) OR KEY (Neural network or Supervised Learning or Unsupervised Learning or Reinforced Learning)))).

Citations to these publications were collected from the date of publication until the 16th June 2021. The retrieved data has been analyzed with Bibliometrix R Package [14]and VOSviewer.

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3 RESULTS AND DISCUSSION

The global research on the "Application of artificial intelligence to Covid-19" accumulated a total of 1142 papersduring 2020-21.Most of these papers were published in the English language with few (n = 9) published in Chinese, Russian, Spanish and French languages. The 1142 global publications on this theme were published in 10 documents types, with "articles" and "conference papers" contributing the largest shares (59.28% and 22.59%), followed by reviews (7.18%), book chapters (3.42%), editorials (2.8%), notes and letters (2.1% each), short surveys (0.35%), erratum and data paper (0.09% each).

31 MOST PRODUCTIVE COUNTRIES

The distribution of global research on the "Application of artificial intelligence to Covid-19" domain was highly skewed by country of papers. In all, 87 countries participated in global research in the subject, of which 41 countries contributed 1-5 papers each, 15 countries 6-10 papers each, 24 countries 11-50 papers, 6 countries 51-100 papers each and only 3 countries more than 100 papers each. The top 10

countries contributed 49 to 246 papers and together account for 92.64% and more than 100.0% share in global publications and citations in this area. .Three countries, namely USA, India and China contributed more than the group average of all top 10 countries papers: USA (246 papers), India (223 papers) and China (153 papers). Five countries registered average citation per paper and relative citation index above the group average (7.75 and 1.15) of all 10 countries: Turkey (15.87 and 2.36), U.K. (11.60 and 1.73), China (8.93 and 1.33), Iran (8.88 and 1.32) and United States (7.87 and 1.17) (Table 1). .

Table 1. Publication and Citation Profile of Top 10 Countries

S.No.	Country	TP	TC	CPP	RCI
1	United States	246	1937	7.87	1.17
2	India	223	1285	5.76	0.86
3	China	153	1366	8.93	1.33
4	United Kingdom	91	1056	11.60	1.73
5	Saudi Arabia	75	258	3.44	0.51
6	Italy	63	484	7.68	1.14
7	Turkey	55	873	15.87	2.36
8	Egypt	52	254	4.88	0.73
9	Iran	51	453	8.88	1.32
10	Australia	49	230	4.69	0.70
	Total of top 10 countries	1058	8196	7.75	1.15
	Global total	1142	7673	6.72	1.00
	Share of top 10 in global total	92.64			

TP=Total papers; TC=Total citations; CPP=Citations per paper

Figure 1 shows a collaborative network map for the top 17 countries. The countries with same colour belong to a single cluster. The degree of their research collaboration is represented by the thickness of the ties between the countries and the distance between them. The greater the diameter and font size of a network node, the greater its weight in research collaboration. India is the most populous country in red cluster, followed by China in the green cluster, and the United Statesinthe blue cluster.

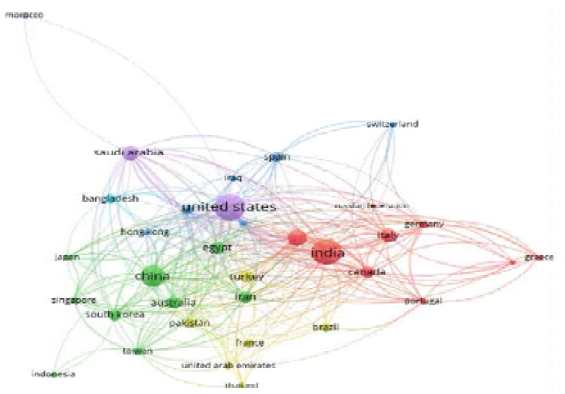

Figure 1 – International collaboration network

32 SUBJECT-WISE DISTRIBUTION

The Covid-19 related AI papers were classified into 27 broad disciplines as per the Scopus database. Among them, computer science, medicine and engineering are the three top subject areas, followed distantly by other subjects (Table 3). In the Scopus database, papers are categorised into different subjects according to the journals of publication. For example, the journal, Computers in Biology and Medicine is classified into two subjects: medicine and computer science. As a result, the sum of the paper shares is not equal to the total number of papers (n = 1142).

Table 2. Distribution of Papers by Broad Subject Categories

S.No.	Subject	TP	Share	S.No.	Subject	TP	Share
1	Computer Science	590	51.66	11	Energy	40	3.50
2	Medicine	426	37.30	12	Environmental Science	32	2.80
3	Engineering	373	32.66	13	Multidisciplinary	28	2.45
4	Mathematics	157	13.75	14	Neuroscience	26	2.28
5	Biochemistry, Genetics and Molecular Biology	127	11.12	15	Agricultural and Biological Sciences	25	2.19
6	Physics and Astronomy	105	9.19	16	Chemical Engineering	24	2.10
7	Materials Science	94	8.23	17	Pharmacology, Toxicology and Pharmaceutics	24	2.10
8	Decision Sciences	83	7.27	18	Immunology and Microbiology	23	2.01
9	Health Professions	79	6.92	19	Chemistry	22	1.93
10	Social Sciences	46	4.03		Global total		

321 SIGNIFICANT KEYWORDS

There are 7688 keywords which were assigned to 1142 papers in the Covid-19 related AI. Of which, keywords used at least 50 times is listed in Table 4. For a clear understanding of the application of AI in Covid-19, duplicated and irrelevant keywords were discarded. Top three keywords are, deep learning, artificial intelligence and machine learning, apart from Covid-19 which shows the appropriateness of the selection of keywords. To explore the relationship of these keywords, co-occurrence network has been generated in VOSviewer (Figure 2). The top keywords were divided into 3 clusters: cluster 1 with a red color led by "deep learning" among the 11 keywords, followed by cluster 2 with a green color led by "diagnostic imaging" among the 9 keywords, and cluster 3 with a blue color led by "Covid-19" among the 5 keywords. Most importantly, the search terms (Covid-19, artificial intelligence and machine learning) used in this paper were grouped under the same cluster (blue).

Table 3. Frequency of Appearance of Significant Keywords

S.No.	Keyword	Frequency	Cluster
1	Covid-19	811	3
2	Deep Learning	672	1
3	Artificial Intelligence	496	3
4	Machine Learning	457	3
5	Diagnosis	294	1

Table 3. Frequency of Appearance of Significant Keywords

6	Convolutional Neural Networks	269	1
7	Learning Systems	206	1
8	Computerized Tomography	175	1
9	Transfer Learning	134	1
10	Diagnostic Imaging	131	2
11	Algorithm	124	2
12	Deep Neural Networks	120	1
13	Forecasting	99	3
14	"Neural networks, computer"	97	2
15	Medical Imaging	97	1
16	Artificial Neural Network	73	2
17	Neural Networks	73	1
18	Image Processing	71	2
19	Image Analysis	69	2
20	Image Classification	66	1
21	Feature Extraction	65	2
22	Image Segmentation	65	2
23	Learning Algorithms	54	3
24	Network Architecture	54	1
25	Support Vector Machine	53	2

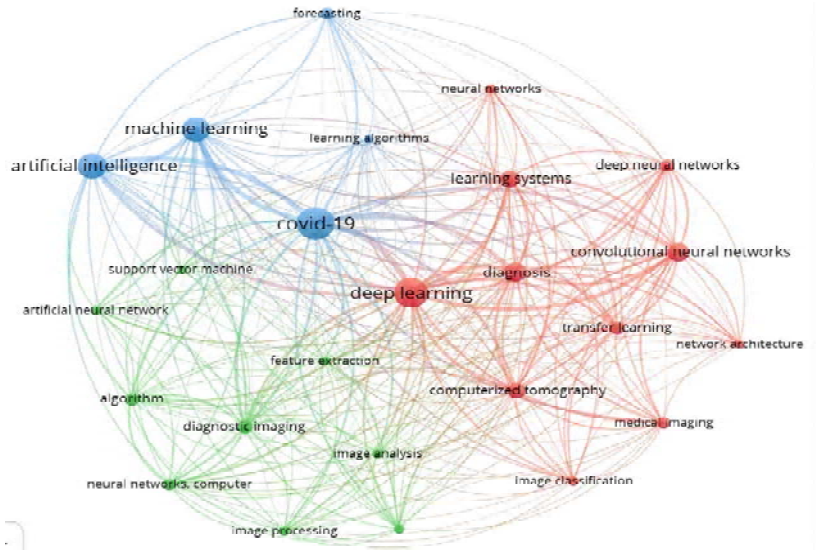

Figure 2.Co-occurrence Network of Keywords

33 MOST PRODUCTIVE ORGANISATIONS

In total, the authors from 2089 institutions have participated in the Covid-19 related AI research. Of these, 1468 institutions published one paper each, 325 institutions published two papers each, 118 institutions published three papers eachand 178 institutions published three or more papers. There are 15 institutions which have published at least 11 papers (Table 4). Of the top 15 organisations, 5 are from China, 3 from Saudi Arabia, 2 from Egypt and 1 each from Canada, Cyprus, Iran, U.K. and USA.

The top 15 organisations individually contributed 11 to 26 papers and together contributed 18.65% and 28.75% share in global publications and citations. On further analysis, it was observed that: (i) Five organisations have contributed more than average group productivity (14.2): King Saud University, Saudi Arabia (26 papers), Near East University, Cyprus (20 papers), King Abdulaziz University, Saudi Arabia (18 papers), Imperial College London, U.K.and Taif University, Saudi Arabia (15 papers each); (ii) Six organisations have registered citations per paper and relative citation index above their group average (10.36 and 1.54): Wuhan University, China (26.09 and 3.88), Tongji Medical College, China (25.42 and 3.78), Ministry of Education, China (23.46 and 3.49), Huazhong University of Science & Technology, China (21.79 and 3.24), Cairu University, Egypt (10.77 and 1.6) and University of Toronto, Canada (10.73and 1.6)(Table 5)

Table 4. Profile of Top 15 Most Productive Organisations

S.No.	Name of the Organization	TP	TC	CPP	HI	ICP	%ICP	RCI
1	King Saud University, Saudi Arabia	26	121	4.65	5	21	80.77	0.69
2	Near East University, Cyprus	20	203	10.15	7	15	75.00	1.51
3	King Abdulaziz UNiversity, Saudi Arabia	18	88	4.89	4	14	77.78	0.73
4	Imperial College London, U.K.	15	76	5.07	3	17	113.33	0.75
5	Taif University, Saudi Arabia	15	76	5.07	3	11	73.33	0.75
6	Huazhong University of Science & Technology, China	14	305	21.79	7	5	35.71	3.24
7	Ministry of Education,, China	13	305	23.46	7	6	46.15	3.49
8	Cairu University, Egypt	13	140	10.77	4	5	38.46	1.60
9	Tongji Medical College, China	12	305	25.42	7	5	41.67	3.78
10	Mansoura University, Egypt	12	25	2.08	2	6	50.00	0.31
11	University of Electronic Science & Technology, China	11	48	4.36	2	7	63.64	0.65
12	University of Toronto, Canada	11	118	10.73	3	7	63.64	1.60
13	Tehran University of Medical Sciences, Iran	11	89	8.09	3	8	72.73	1.20
14	Wuhan University, China	11	287	26.09	5	4	36.36	3.88
15	Massachusetts General Hospital, USA	11	20	1.82	3	6	54.55	0.27
	Total of 15 organizations	213	2206	10.36	65	137	64.32	1.54
	Global total	1142	7673	6.72				
	Share of top 15 organizations in global total	18.65	28.75					

TP=Total papers; TC=Total citations; CPP=Citations per paper; ICP=International collaborative papers; RCI=Relative citation index

34 MOST PRODUCTIVE AUTHORS

In total, 5069 authors were found to have contributed to the Covid-19 related AI research. Of these, 86.1% authors have contributed one paper each, more than 9%authors two papers each, 2.5% authors three papers each and 2.2% authors have contributedmore than three papers. The top 15 authors had at least 5 papers each. These top authors originated from the United States (n = 3), China, India, Turkey and U.K. (n=2 each),Bangladesh, Egypt, Iraq and Italy (n = 1 each).

The top 15 authors individually contributed 5 to 11 papers and together contributed 7.53% and 11.51% share in global publications and citations. On further analysis, it was observed that: (i) five authors have contributed papers above the

group average productivity (573): F. Al-Turjman (Turkey)(11 papers), A.E. Hassanien (Egypt)(7 papers), L. Saba (Italy), D. Gupta (India) and T.Q. Duong (USA)(6 papers each); (ii) Six authors have registered citation per paper and relative citation index above their group average (10.27 and 1.53): D. Shen (China) (26.20 and 3.9), A. Khanna (India)(24.8 and 3.69), Y. Zha (China)(23.6 and 3.51), D. Gupta (India)(17. 0 and 2.53), F. Al-Turjman (Turkey)(12.73 and 1.89) and S.A. Fattah (Bangladesh)(10.8 and 1.61).

To explore the relationship in terms of research collaboration between these top 15 authors, a co-authorship network map has been generated (Figure 3). There are three research groups among the top 15 authors and almost 7 authors did not collaborate with other top authors.

Table 5. Profile of Top 15 Most Productive Authors

S.No.	Name of the Author	Affiliation of the Author	TP	TC	CPP	RCI
1	F. Al-Turjman	Antalya Bilim University, Turkey	11	140	12.73	1.89
2	A.E. Hassanien	Cairo University, Egypt	7	7	1.00	0.15
3	L. Saba	Azienda Ospedaliero Universitaria di Cagliari, Italy	6	27	4.50	0.67
4	D. Gupta	Maharaja Agrasen Institute of Technology, India	6	102	17.00	2.53
5	T.Q. Duong	Albert Einstein College of Medicine of Yeshiva University, USA	6	47	7.83	1.17
6	J.S. Suri	Athero Point LLC, USA	5	18	3.60	0.54
7	M.A. Mohammed	University Of Anbar, Iraq	5	50	10.00	1.49
8	D. Shen	Shanghai United Imaging Intelligence Co., Ltd., China	5	131	26.20	3.90
9	Y. Zhang	University of Leicester, U.K.	5	21	4.20	0.63
10	S. Serte	Yakin Doğu University Turkey	5	2	0.40	0.06
11	M. Mahmud	Nottingham Trent University, U.K.	5	24	4.80	0.71
12	S.A. Fattah	Bangladesh University of Engineering and Technology, Bangladesh	5	54	10.80	1.61
13	A.Khanna	Maharaja Agrasen Institute of Technology, India	5	124	24.80	3.69
14	Y. Zha	Renmin Hospital of Wuhan University, China	5	118	23.60	3.51
15	S. Naidu	University of Minnesota Duluth, USA	5	18	3.60	0.54
	Total of 15 authors		86	883	10.27	1.53
	Global total		1142	7673	6.72	
	Share of top 15 authors in global total		7.53	11.51		

TP=Total papers; TC=Total citations; CPP=Citations per paper; ICP=International collaborative papers; RCI=Relative citation index

Figure 3.Co-authorship Network of Top 15 authors

35 SIGNIFICANT PUBLICATION SOURCES

The total papers were published in 542 different sources including journals, conference proceedings, books etc. Of the 542 sources, the top 15 sources published more than 21% of the total papers (having at least 10 papers each) (Table 6). There is a mix of computer science and medical journals among the top sources along with two multidisciplinary journals. Top two journals are IEEE Access and Journal of Medical Internet Research: former one is a multidisciplinary open access journal published by IEEE and later is also an open access medical journal.

Table 6. Profile of Top 15 Sources

S.No.	Name of the Source	TP	% TP	TC	CPP
1	IEEE Access	33	2.89	446	13.52
2	Journal of Medical Internet Research	27	2.36	143	5.30
3	Computers in Biology and Medicine	19	1.66	673	35.42
4	Computers Materials and Continua	19	1.66	26	1.37
5	Chaos Solitons and Fractals	16	1.40	392	24.50
6	Applied Intelligence	15	1.31	179	11.93
7	IEEE Journal of Biomedical and Health Informatics	15	1.31	81	5.40
8	International Journal of Environmental Research and Public Health	15	1.31	79	5.27
9	IEEE Transactions on Medical Imaging	14	1.23	576	41.14
10	ACM International Conference Proceeding Series	12	1.05	11	0.92
11	Biomedical Signal Processing and Control	12	1.05	44	3.67
12	Informatics in Medicine Unlocked	12	1.05	172	14.33
13	Lecture Notes in Computer Science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics)	11	0.96	16	1.45
14	PLOS One	11	0.96	40	3.64
15	Advances in Intelligent Systems and Computing	10	0.88	1	0.10
TP=Total papers; TC=Total citations; CPP=Citations per paper					

36 HIGHLY-CITED PUBLICATIONS

Out of total 1142 publications on this theme, 27 papers (15.59% % share) received 71 to 394 citations from the date of publication to the date of access on 26.7.2021. These 27 papers are assumed here as highly-cited papers. Together these 27 papers received a total of 3823citations since their publication, with an average of 141.59 citations per paper.

Of the 27 highly-cited papers (23 articles, 2 reviews and 1 each as editorial and notes), 5 papers involve zero collaboration and the remaining 22 papers involve more than one organisation (13 national collaborative and 9 international collaborative).

18 countries participated in 27 high-cited papers, of which USA and India

contributed the largest number of papers (6 each), followed by China and Turkey (4 papers each), Singapore and U.K. (3 papers each), Brazil, Iran and Italy (2 papers each), Canada, Egypt, Greece, Japan, Malaysia, Mexico, South Korea, Taiwan and U.A.E (1 paper each).

The 27 high cited papers involve 90 organisations and 178 authors and they are published in journals: *IEEE Transactions in Medical Imaging* (4 papers), *Computers Methods & Programs in Biomedicine* and *Computers in Biology & Medicine* (3 papers each), *Chaos Solitons & Fractals* (2 papers each) and 1 paper each in 15 other journals.

4 CONCLUSION

This study analyses the global research output (1142 records) in Covid-19 related AI indexed in Scopus database with quantitative and qualitative matrices. It focuses on productivity of leading participating countries, organisations, authors and journals and presents an analysis of collaborative networks and network linkages between them. The analysis and results presented in this study may be of interest to policy-makers and other stakeholders, especially to those in developing countries. It will help them understand the status of Covid-19 related AI research in their respective countries. It will also guide them in evolving strategies to plan investments in COVID-19 related AI research aimed at strengthening research infrastructure, and opening of new programsfor manpower development and collaboration in the domain.

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