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A Bibliometric Analysis of Artificial Intelligence applications during COVID-19 Based on Web of Science (WoS) Database

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Abstract: This article opens up another analytic method of Artificial Intelligence applications in Light of COVID-19, mainly explaining this binding domain's current trends and knowledge areas, according to the data analysis of previous studies in this field.

The bibliometric study was performed to present new research trends in Artificial Intelligence in light of COVID-19. The data of 1635 studies published in Web of Science were analyzed during the last two years (2020-2021). We achieved the bibliometric analysis using three software CiteSpace, VOSviewer, and KnowledgeMatrix Plus.

The findings of bibliometric analysis suggest that there are twelve research clusters in this topic (emerging industry, cross-sectional survey study, emerging technologies, joint position paper, colony predation algorithm, medical worker, deep learning, covid-19 risk prediction, future smart connected communities, supply chain resilience, virtual screening, and k-12 students). The United States, People's Republic of China, the United Kingdom, India, Saudi Arabia, Italy, Australia, Spain, South Korea, and Canada are the most intriguing countries that investigated this issue during COVID-19, so this study reveals the latest policy trends in Artificial intelligence using bibliometric analysis.

Keywords: Bibliometric review; Artificial Intelligence; COVID-19; Machine learning, Web of Science (WoS).

تحليل ببليومتري للذكاء الاصطناعي- خلال COVID-19 بناءً على بيانات WOS

عبد المجيد الغامدي
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المستخلص: تعالج هذه الورقة البحثية طريقة تحليلية أخرى لتطبيقات الذكاء الاصطناعي في ظل كوفيد 19، وتشرح بشكل أساسي الاتجاهات الحالية ومجالات المعرفة، من خلال تحليل بيانات الدراسات السابقة في هذا المجال.

تم القيام بالدراسة الببليومتري لتقديم اتجاهات بحثية جديدة في تطبيقات الذكاء الاصطناعي في ظل كوفيد 19، من خلال تحليل بيانات 1635 دراسة نُشرت في قاعدة المعرفة (Web of Science) خلال العامين الماضيين (2020-2021). قمنا بالتحليل الببليومتري باستخدام ثلاثة برامجيات CiteSpace و VOSviewer وKnowledgeMatrix Plus .

تشير نتائج التحليل الببليومتري أن هناك اثني عشر مجموعة بحثية في هذا المجال (الصناعات الناشئة، المسح المقطعي، التقنيات الناشئة، الموقف المشترك، خوارزمية الافتراس المكروبي، العامل الطبي، التعلم العميق، التنبؤ بمخاطر كوفيد 19، المجتمعات الذكية، مرونة سلسلة التوريد، الفحص الافتراضي، طلاب K-12). أيضا تتمثل الدول الأكثر اهتماما للبحث في هذه الاشكالية في الولايات المتحدة الأمريكية، جمهورية الصين الشعبية، المملكة المتحدة، الهند، المملكة العربية السعودية، إيطاليا، أستراليا، إسبانيا، كوريا الجنوبية وكندا. تكشف هذه الدراسة في الأخير عن أحدث السياسات للاتجاه لتطبيقات الذكاء الاصطناعي.

الكلمات المفتاحية: مراجعة ببليومترية؛ ذكاء اصطناعي؛ كوفيد 19، تعلم الآلة، قاعدة المعرفة..Web of Science (WoS)

1. Introduction.

The COVID-19 pandemic has been around for nearly two years, and it is time to prepare for the post-Covid-19, as artificial intelligence (AI) is being relied upon, which has actively contributed to containing the global health crisis. (Adadi, A., Lahmer, M., & Nasiri, S., 2021). Dobson-Lohman, E., and Potcovaru, A.-M. (2020) conducted analysis and provided estimates regarding the relationship between COVID-19 anxiety, emotional contagion, and responsible media reporting. Accordingly, many areas of research and trends appeared in this field.

In addition, Lyons, N., and Lăzăroiu, G. (2020) examined the application of machine learning algorithms in data-driven smart sustainable cities and turned up with several estimates. Empirical evidence for health services during the COVID-19 pandemic has been hard to find in the literature. Analyses and estimates have been made about how digital technologies and data-driven telemedicine could be used in smart healthcare during the COVID-19 pandemic (Davis, 2020).

Artificial intelligence in Healthcare has been one of the research fields that many researchers have been interested in including (Chen, 2016; Lancet, 2017; Mahajan, 2018; Chen & Jain, 2019; Bohr & Memarzadeh, 2020; Catania, 2020; Lawry, 2020; Nordlinger, Villani, & Rus, 2020; Sisodia, Pachori, & Garg, 2020). AI in Healthcare is related to the study of intelligent agents that develop the ability to learn, reason, and react to situations not programmed into the medical machines. As the applications of AI and machine learning in health care have increased since the beginning of the Corona pandemic.

As a result of the growth and adoption of solutions based AI, the use of AI is having a profound impact. This review defends the AI literature on Covid-19, which is needed at this time, if we have to keep pace with the changing realities of AI and the paradigm shifts caused by the pandemic. Accordingly, As a result, the review's objective is to provide a more clear overview of what's available in the literature on AI applications in COVID-19 without having to read the entire state-of-the-art studies. Next, we think it would be a great way to give researchers who are excited for the new literature a position where they can quickly get a broad picture of what's out there without having to read through all of the previous studies.

AI recognized another sub-field, is machine learning, which many researchers have also been attracted in, including: (Muniasamy *et al.*, 2019; Panesar, 2019; Agrawal *et al.*, 2020; Jain & Chatterjee, 2020; Mohanty, Nalinipriya, Jena, & Sarkar, 2021). As a branch of artificial intelligence concerned with designing and developing algorithms and techniques that allow computers to learn medical issues. In COVID-19, the number of publications in machine learning applications rose.

Previous studies indicate that many sub-fields and applications of Artificial Intelligence, which are deep learning, deep neural networks, conventional neural networks, computer-assisted diagnosis, radiography thoracic, diagnostic imaging, mortality, physiology, respiratory syndrome, severe acute. (Baldi, 2018; Cheon *et al.*,2019; Yazhini, K., & Loganathan, 2019; Basiri *et al.,* 2020; Hossain, McKyer & Ma, 2020). Many authors, countries, and research institutions have been interested in research in this

area. (De Felice and Polimeni, 2020; Hossain, McKyer & Ma, 2020; Naseem, 2020; Abd-Alrazaq et al., 2021). Therefore, the research objectives of this study are as follows:

RQ: In the Web of Science (WoS) database, what are the most intriguing study fields, authors, countries, and institutions in the Artificial Intelligence applications during COVID-19?

RQ1. What are the most interesting sub-areas in the subject of artificial intelligence during the COVID-19 in the Web of Science (WoS) database?

RQ2. Which keywords are most frequently occurring in studies of artificial intelligence during COVID-19 in the Web of Science (WoS) database?

RQ3. Which authors are most cited in studies of artificial intelligence during COVID-19 in the Web of Science (WoS) database?

RQ4. Which countries are most interested in the research of artificial intelligence during COVID-19 in the Web of Science (WoS) database?

RQ5. Which institutions are most interested in the research of artificial intelligence during COVID-19?

2. Methods.

Bibliometric analysis is one of the science mapping fields which uses methods to analyze data of previous research works and study how articles, authors, areas, and resources are related to one another (five methods are using Citation, Co-citation, Bibliographic coupling, Co-author, and Co-word), to define the critical areas of research, keywords, authors, countries, and organizations in a specific field of knowledge (Zupic & Čater, 2015) such as Artificial Intelligence in COVID-19.

A search of the Web of Science database was done to find previously published papers on the topic of "Artificial Intelligence during COVID-19." The studies were chosen using the following criteria: First, search for "Artificial Intelligence" and "COVID-19" in the titles, abstracts, and keywords. Second, note and letter have been eliminated from the document type editorial. Third, the subject areas were confined to a selection of works in the disciplines of computer science, medicine, engineering, and health professions that dealt with this topic. As a consequence,1635 articles were found and distributed, as shown in Figure 1.

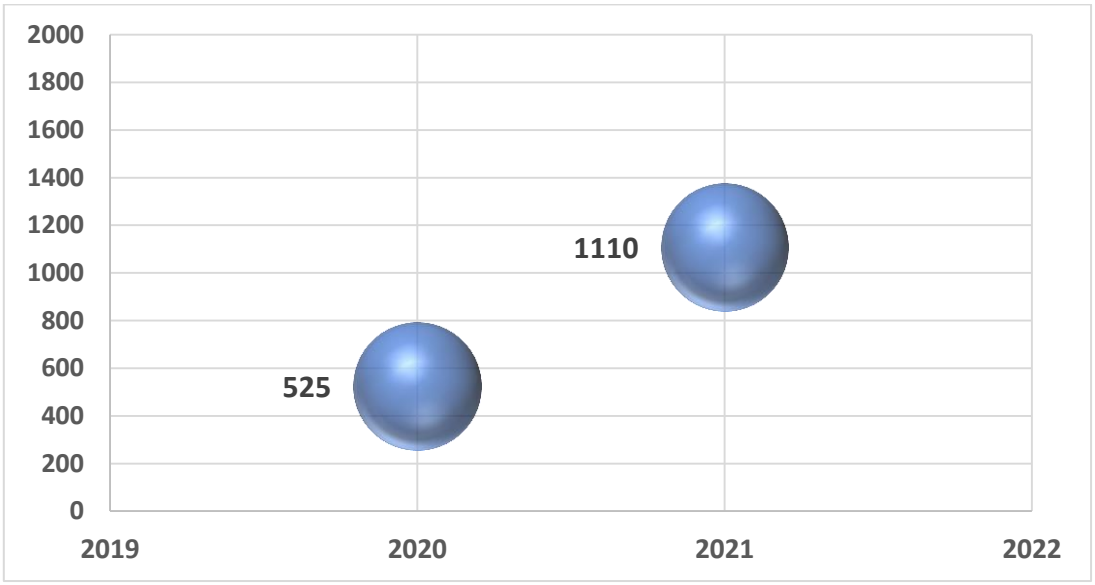

Figure (1) Publications per year (Knowledge Matrix Plus and Excel outputs)

Figure 1 illustrates the distribution of the number of studies used in the bibliometric analysis predicts 525 studies in 2020 and 1110 studies in 2021, for a total of 1635 publications. According to statistics, it increased steadily between 2020 and 2021, and is predicted to hit new highs in 2022. The following figure depicts the various sorts of these publications.

Figure (2) Types of publications (Knowledge Matrix Plus and Excel outputs)

Figure 2. indicates that the search was limited to the following articles: Article (1485), Article; Early Access (159), Article; Proceedings Paper (14), Article; Book Chapter (2), and Article; Data Paper (2). This indicates that this is one of the topics in which researchers from all over the world are interested, particularly in light of the Corona pandemic.

To prepare the bibliometric review, two approaches have been used the number of publications and citations, to find the relationship between Sub-areas, keywords, authors, countries, and organizations,

based on outputs of three software's: CiteSpace is an information visualization tool that translates research domain notions into mapping functions between research frontiers and intellectual bases (Chen, 2016), Knowledge Matrix Plus is an advanced tool for evaluating statistics and frequency (KISTI, 2016) and is a sophisticated function in co-occurrence and citation analysis that was used to create the networks (Van Eck & Waltman, 2013)

3. Results.

3.1 Results of the bibliometric analysis of Sub-areas

Figure 3 and Table 1 depict the most important sub-areas of artificial intelligence research and development during the Covid-19 epidemic.

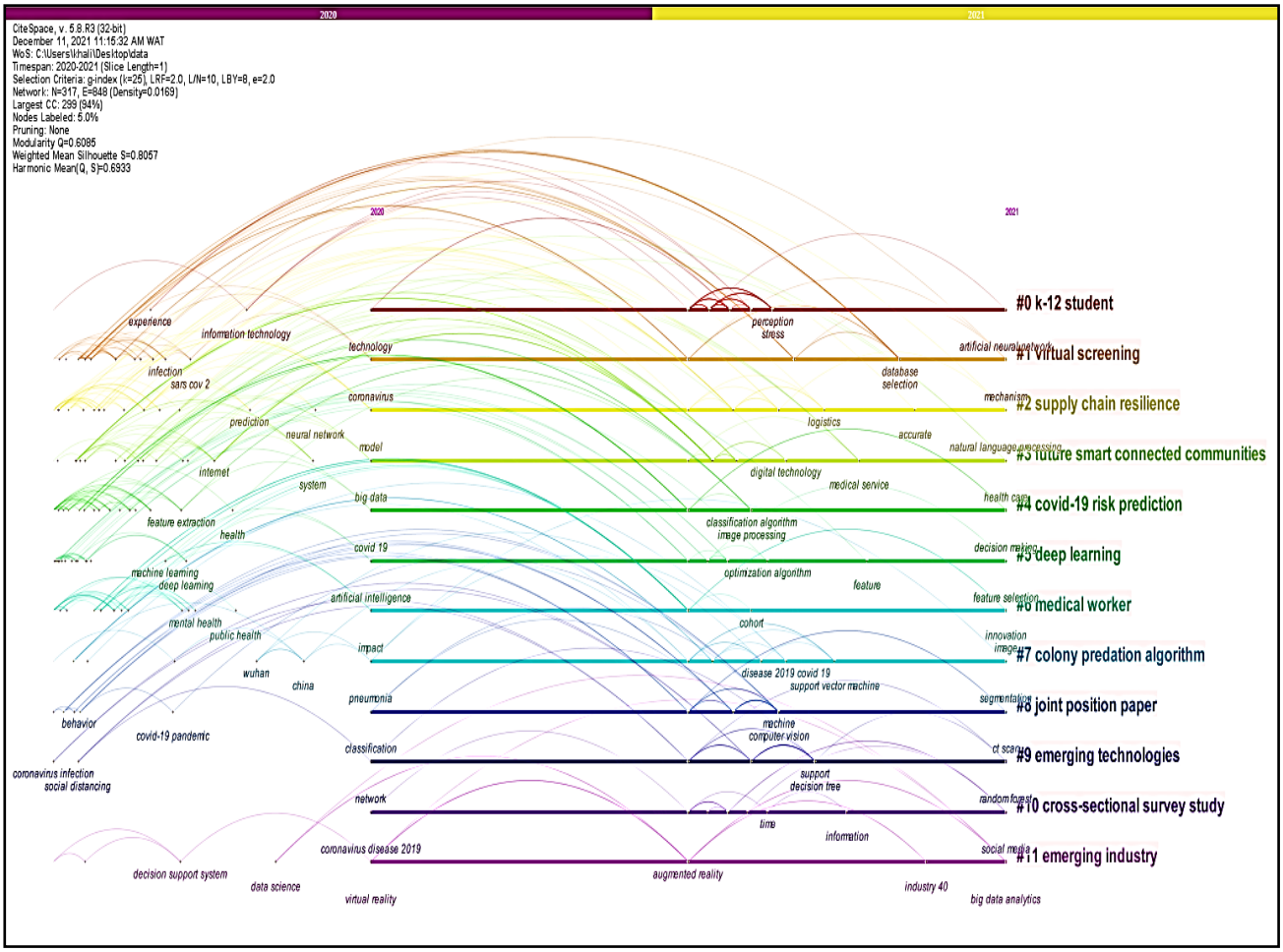

Figure (3) Visualization of sub-areas by time series (CiteSpace outputs)

Trying to construct a set of features and involved indicators that support these elements when examining other important pieces of research and analyzing the relevance of the obtained results, we attempted to confirm the implications of the findings in the bibliometric mapping.

Table (1) The most important sub-areas (clusters) in Artificial Intelligence during COVID-19

Cluster	Cluster ID	Size	Silhouate	Top terms (Latent Semantic Indexing LSI)	Terms (mutual information)
Emerging industry	11	10	0.878	to-end deep learning framework; covid-19 crisis; exploratory analysis; contemporary digital tool; virtual reality | supply chain innovation; emerging industry; virtual reality; needs theory; mr system	artificial intelligence (0.02); covid-19 pandemic (0.02); deep learning (0.01); industrial setting (0.01); healthy workplace (0.01)
Cross-selectional survey study	10	14	0.904	covid-19 pandemic; cross-sectional survey study; social media engagement; influenza vaccination; dental care | environmental challenge; developing countries; environmental research; security threat; artificial intelligence	first wave (0.05); covidpain tweet (0.05); rapid screening classifier (0.05); ct abnormality (0.05); microscopic segmentation (0.05)
Emerging technologies	9	17	0.793	emerging technologies; comprehensive survey; clinical outcome; veterans affair; designing covid-19 mortality prediction | covid-19 prediction; south korea; using metrics; model development; covid-19 infection cases	ct abnormality (0.09); initial finding (0.09); using novel machine (0.09); laboratory result (0.09); rapid screening classifier (0.09)
Joint position paper	8	18	0.912	using deep learning; joint position paper; european association; personalised medicine; health risk | covid-19 pandemic; artificial intelligence; robust modelling; heterogeneous learning framework; actual market environment	multi-channel transfer learning (0.16); rapid screening classifier (0.16); ct abnormality (0.16); microscopic segmentation (0.16); initial finding (0.16)
Colony predation algorithm	7	19	0.809	covid-19 severity; coronavirus disease; machine learning; covid-19 patient; covid-19 pandemic | assisting scalable diagnosis; geo-based multi-criteria decision support system; complex problem; clinical data; covid-19 outcome	rapid screening classifier (0.21); ct abnormality (0.21); microscopic segmentation (0.21); initial finding (0.21); using novel machine (0.21)
Medical worker	6	26	0.885	covid-19 pandemic; medical worker; covid-19 pneumonia; mental health; ct scan | artificial intelligence; coronavirus disease; policy uncertainty; carbon price; markov-switching dependence	microscopic segmentation (0.37); rapid screening classifier (0.37); ct abnormality (0.37); initial finding (0.37); using novel machine (0.37)

Cluster	Cluster ID	Size	Silhouate	Top terms (Latent Semantic Indexing LSI)	Terms (mutual information)
Deep learning	5	30	0.766	artificial intelligence; covid-19 pandemic; covid-19 pneumonia; covid-19 infection; machine learning | deep learning; covid-19 patient; covid-19 detection; convolutional neural network; chest x-ray	rapid screening classifier (5.58); ct abnormality (5.58); microscopic segmentation (5.58); initial finding (5.58); using novel machine (5.58)
Covid-19 risk prediction	4	30	0.752	covid-19 pandemic; artificial intelligence; pandemic management; using hybrid; machine learning | covid-19 diagnosis; using artificial intelligence; emergency department; coronavirus pandemic; covid-19 risk prediction	rapid screening classifier (0.49); ct abnormality (0.49); microscopic segmentation (0.49); initial finding (0.49); using novel machine (0.49)
Future smart connected communities	3	32	0.773	covid-19 pandemic; covid-19 outbreak; big data; covid-19 cases; future smart connected communities | artificial intelligence; machine learning; using artificial intelligence; using deep learning; pandemic management	rapid screening classifier (0.54); ct abnormality (0.54); microscopic segmentation (0.54); initial finding (0.54); using novel machine (0.54)
Supply chain resilience	2	34	0.756	artificial intelligence; covid-19 pandemic; using artificial intelligence; supply chain resilience; artificial neural network | deep learning; covid-19 patient; covid-19 detection; convolutional neural network; covid-19 pneumonia	rapid screening classifier (0.63); ct abnormality (0.63); microscopic segmentation (0.63); initial finding (0.63); using novel machine (0.63)
Virtual screening	1	34	0.836	virtual screening; machine learning; pathogenetic profiling; sars-like viruses; cov-2 coronavirus | cov-2 neutralizing antibody complexe; binding affinity; advanced bioinformatics; existing therapeutics; natural evidence	rapid screening classifier (0.39); ct abnormality (0.39); microscopic segmentation (0.39); initial finding (0.39); using novel machine (0.39)
K-12 student	0	35	0.766	covid-19 pandemic; efficient air pollution management; smart cities; integrating data-based strategies; social networking site | artificial	rapid screening classifier (0.15); ct abnormality (0.15); microscopic segmentation (0.15);

Cluster	Cluster ID	Size	Silhouate	Top terms (Latent Semantic Indexing LSI)	Terms (mutual information)
				intelligence; artificial neural network; cognitive presence; student satisfaction; learning system	**initial finding (0.15); using novel machine (0.15)**

According to Figure 3 and Table 1, there are 12 sub-fields of research in the subject of artificial intelligence in the Corona pandemic (emerging industry, cross-sectional survey study, emerging technologies, joint position paper, colony predation algorithm, medical worker, deep learning, covid-19 risk prediction future smart connected communities, supply chain resilience, virtual screening, k-12 student), it appears that it is a rich topic whose fields varied according to the diversity of its applications that is identified by (Khan et al. 2021) mostly used machine learning (ML) and deep learning (DL) methods for COVID-19 detection, diagnosis, screening, classification, drug repurposing, prediction, and forecasting, policy and insights (Durana et al., 2020). More emphasis should be placed on the most frequently cited publications in Appendix 1 for research in these sub-areas.

3.2 Results of the bibliometric analysis of Keywords

Figure 4 shows the findings of a bibliometric study or the network of keywords in the Artificial Intelligence theme during COVID-19 using Web of Science (WoS) database.

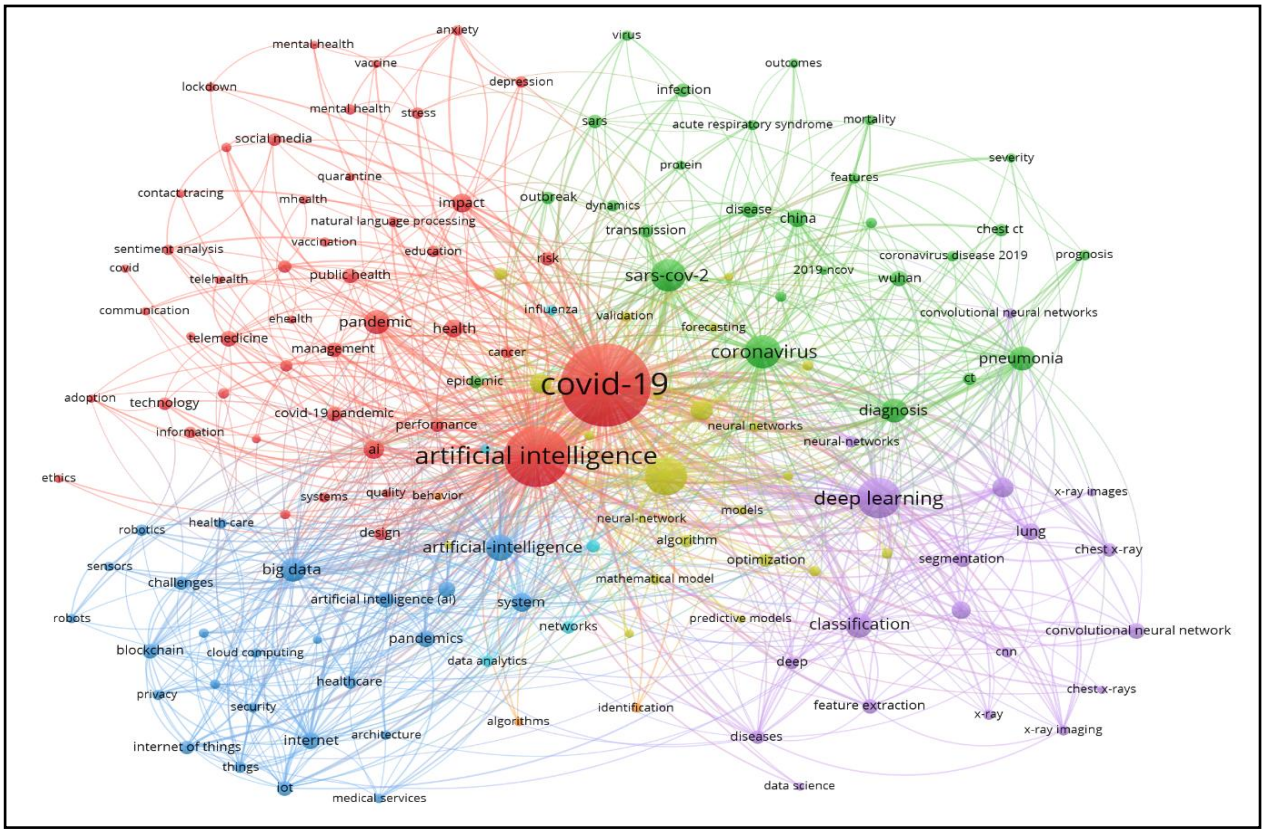

Figure (4) Keywords network (VOSviewer outputs)

Figure 4 illustrates the network of the most frequently occurring keywords in the domain of artificial intelligence during COVID-19 (See Appendix 2), which are as follows: artificial intelligence, deep learning, machine learning, big data, computed tomography, convolutional neural network, chest x-ray, transfer learning, neural network, digital health, x-ray imaging, mental health, artificial neural network, infectious disease, medical service, natural language processing. See also: (Abd-Alrazaq et al., 2021). This is illustrated in greater detail in Appendix 2, the first trend in artificial intelligence research during Covid 19 begins with researching the scientific truth of artificial intelligence (first keywords), then deep learning (second keywords), and then the rest of the fields: machine learning, big data, computed tomography, convolutional neural network, chest x-ray, transfer learning,... and so on.

3.3 Results of the bibliometric analysis of authors

The following figure shows the most influential authors in the field of artificial intelligence during Covid-19, based on the number of researchers' citations.

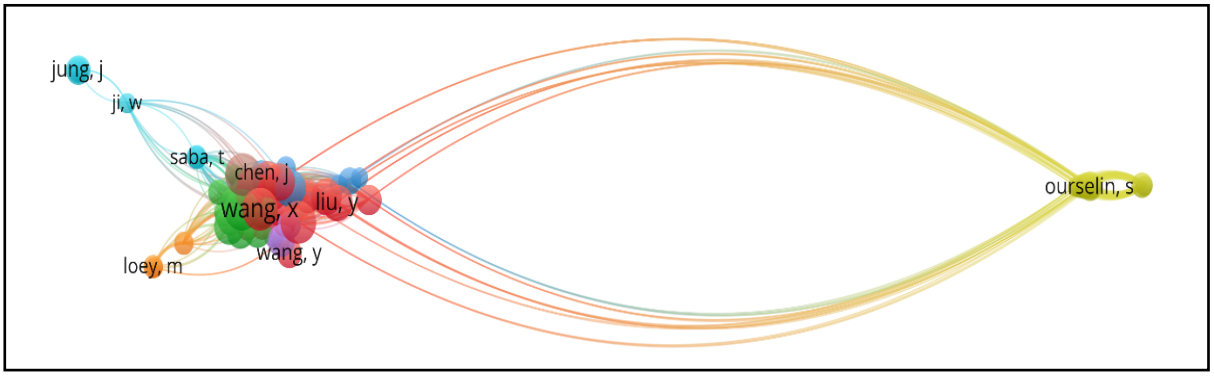

Figure (5) Authors network (VOSviewer outputs)

Figure 5. and Appendix 3. Illustrate that many researchers in the Web of Science have been interested in the topic of artificial intelligence in light of the Corona pandemic, such as Yang, Z; Xia, L; Chen, C; Zhang, Z; Zhang, J; Zhang, T; Liu, X; and Wu, Y. Also, it demonstrates its significance and that it is a current topic, particularly in light of the Corona pandemic. See (Hossain, McKyer & Ma,, 2020) In terms of the number of publications, the figure below depicts the most published authors in the Web of Science (WoS) database.

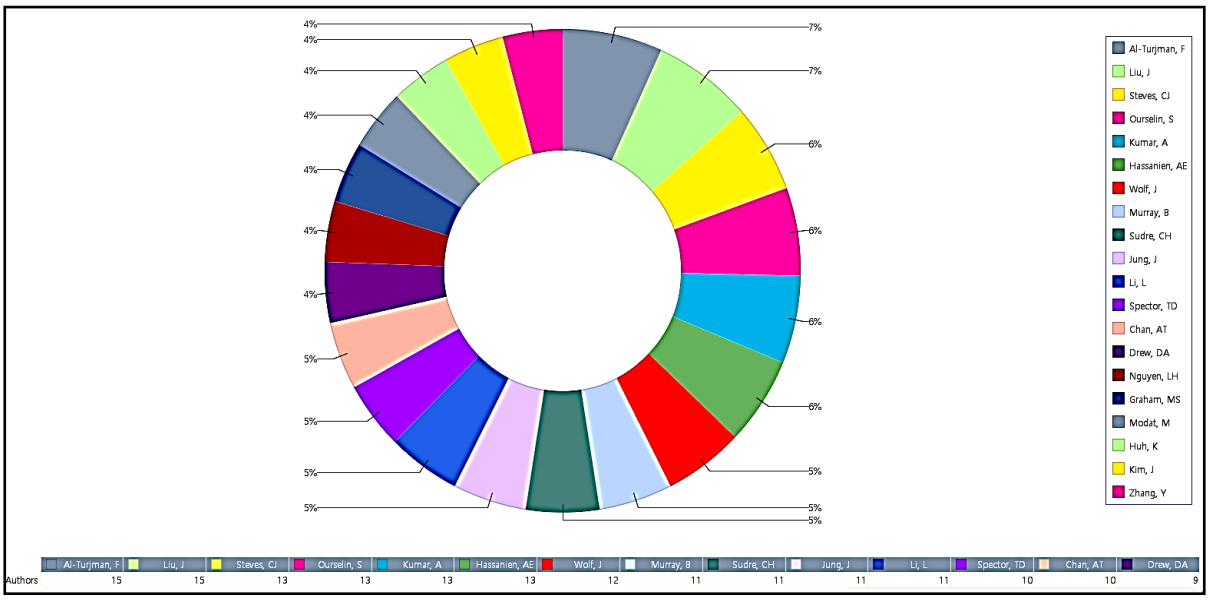

Figure (6) Top Authors in AI during COVID-19 (KnowledgeMatrix Plus outputs)

Figure 6 shows that the most important researchers interested in the publication of artificial intelligence in Covid-19 are, in order: Al-Tudjman, F.; Liu, J.; Steves, CJ.... and others. This necessitates that the researcher on this subject pay close attention to the work of these authors and inform them with special care about their significance.

3.4 Results of the bibliometric analysis of countries

The following figure and Appendix 4 show the countries with the highest number of citations in the Web of Science (WoS) database in the field of artificial intelligence in Covid-19:

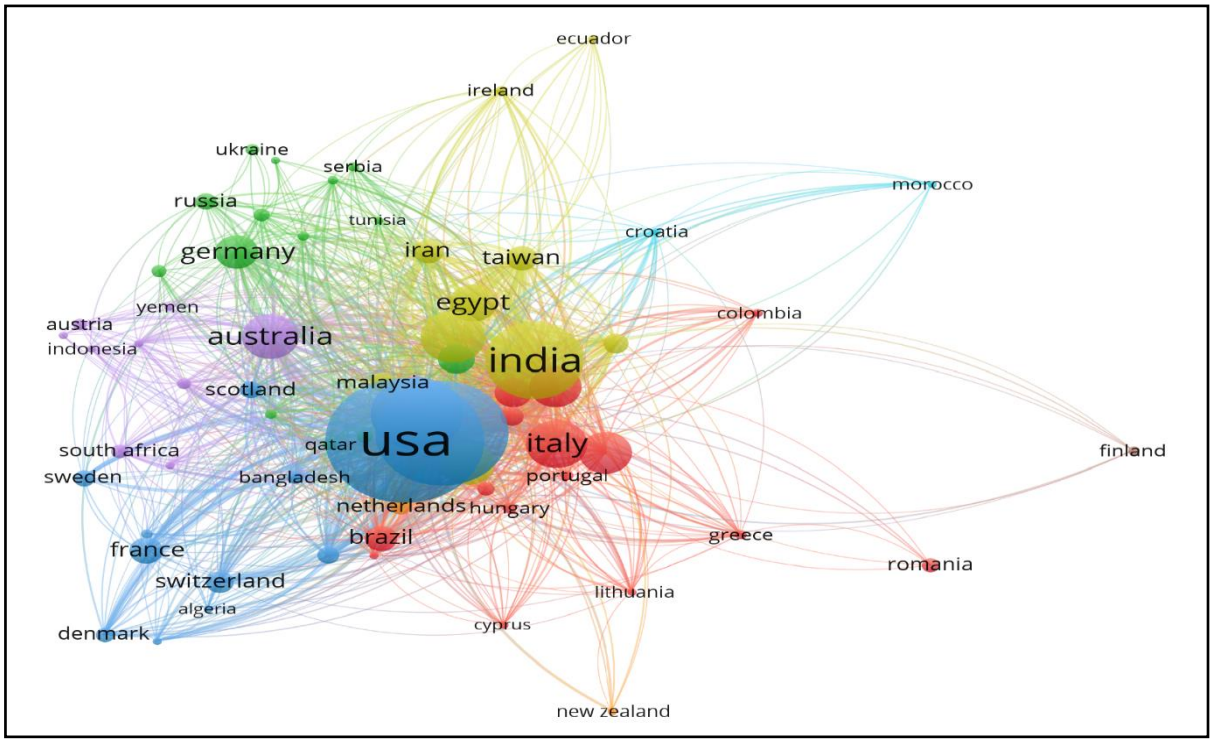

Figure (7) Countries network (VOSviewer outputs)

According to citations in the Web of Science (WoS) database, the following countries are the most important and influential in the field of artificial intelligence in the Corona pandemic: Peoples R of China, the United States, England, the Netherlands, India, Australia, Germany, France, Italy, Taiwan, and so on. As it is shown in the table below, the order changes depending on the number of publications. See also: (De Felice and Polimeni, 2020)

According to the number of publications and citations shown in appendix 4, the following countries appear in the top ten countries in an artificial intelligence topic during COVID-19.

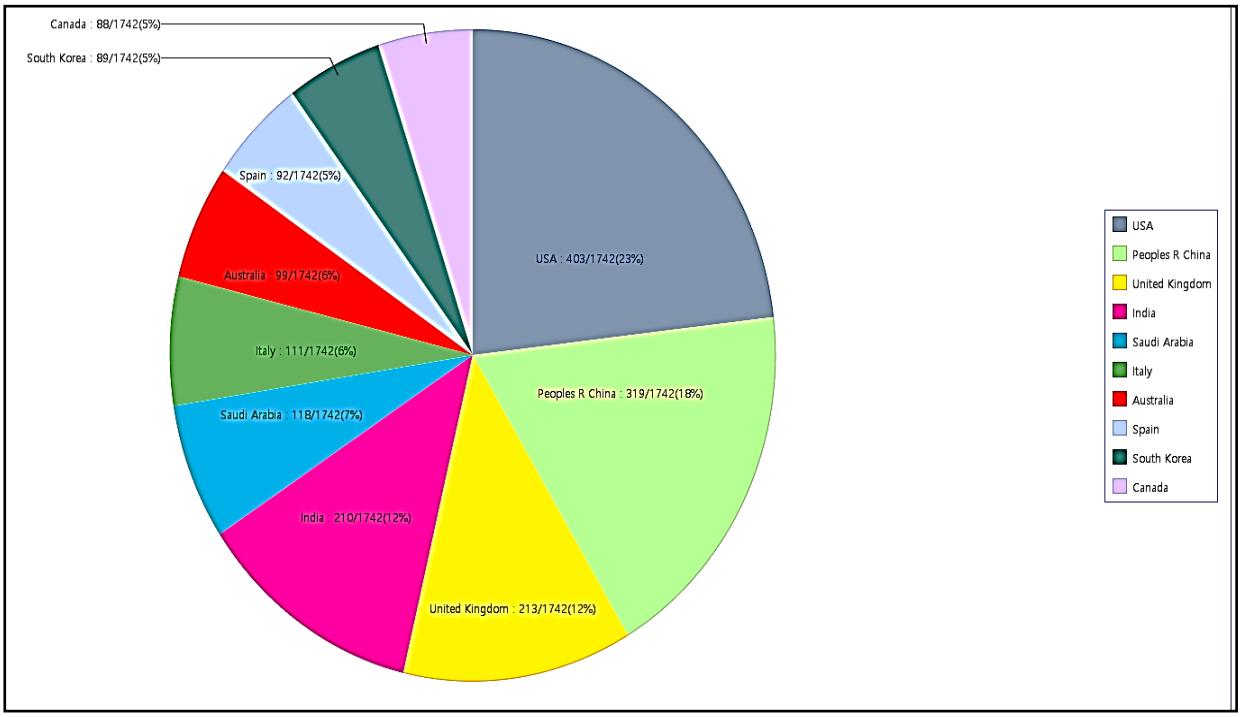

Figure (8) Top countries in AI during COVID-19 (KnowledgeMatrix Plus outputs)

The United States, People's Republic of China, the United Kingdom, India, Saudi Arabia, Italy, Australia, Spain, South Korea, and Canada are among the top 10 countries most publishing and citing on the Web of Science database in the topic of AI during Covid-19, these countries should be acknowledged in artificial intelligence research, reporting, and statistics.

3.5 Results of the bibliometric analysis of organizations

The following figure and appendix 5 depict the most referenced organizations in the world on the topic of artificial intelligence during Covid-19:

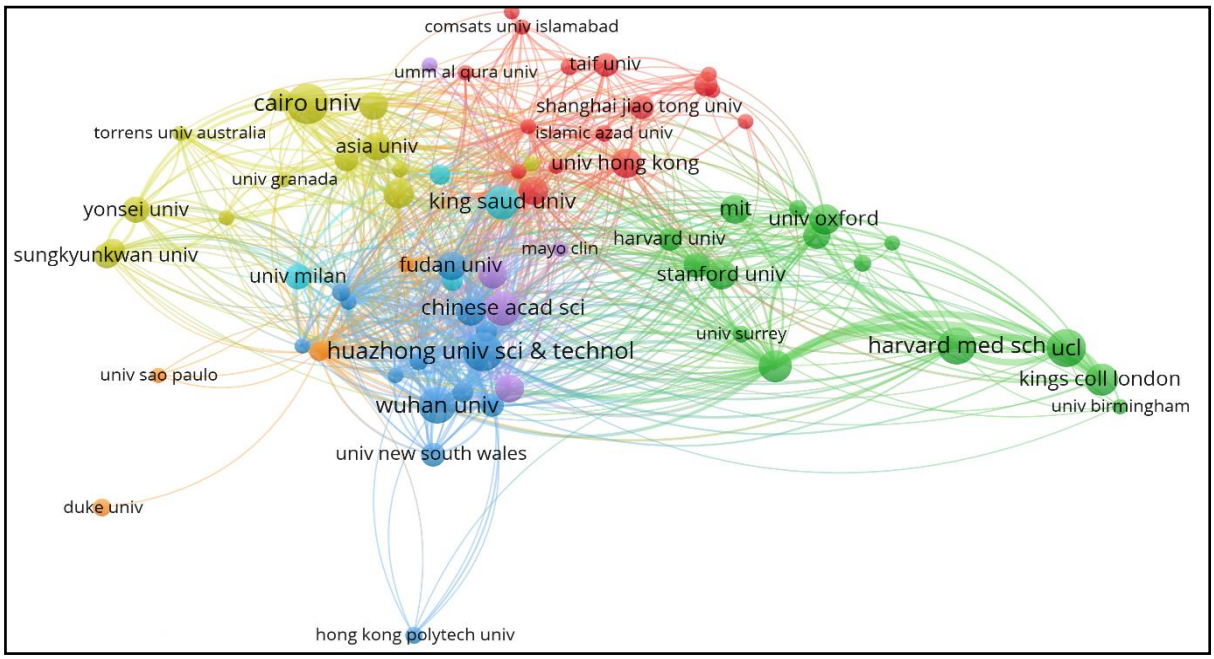

Figure (9) Organizations network (VOSviewer outputs)

Figure 9. and appendix 5 show that the first scientific institutions that were cited in the topic of artificial intelligence in Covid- 19 based on the Web of Science database are: Huazhong University of Science and Technology China (3106 citations and 29 publications), Massachusetts General Hospital USA (1460 citations and 22 publications), King's College London (1238 citations and 22 publications), Harvard Medical School USA (1194 citations and 27 publications), University of Hong Kong China (1054 citations and 20 publications), Zoe Global University (1025 citations and 6 publications),... etc. These research institutions are in the list of the most published and cited countries (figures 7 and 8 and appendix 4) See: (De Felice and Polimeni, 2020)

This arrangement may differ if we rely on the citation and publication indicators as shown in the following figure.

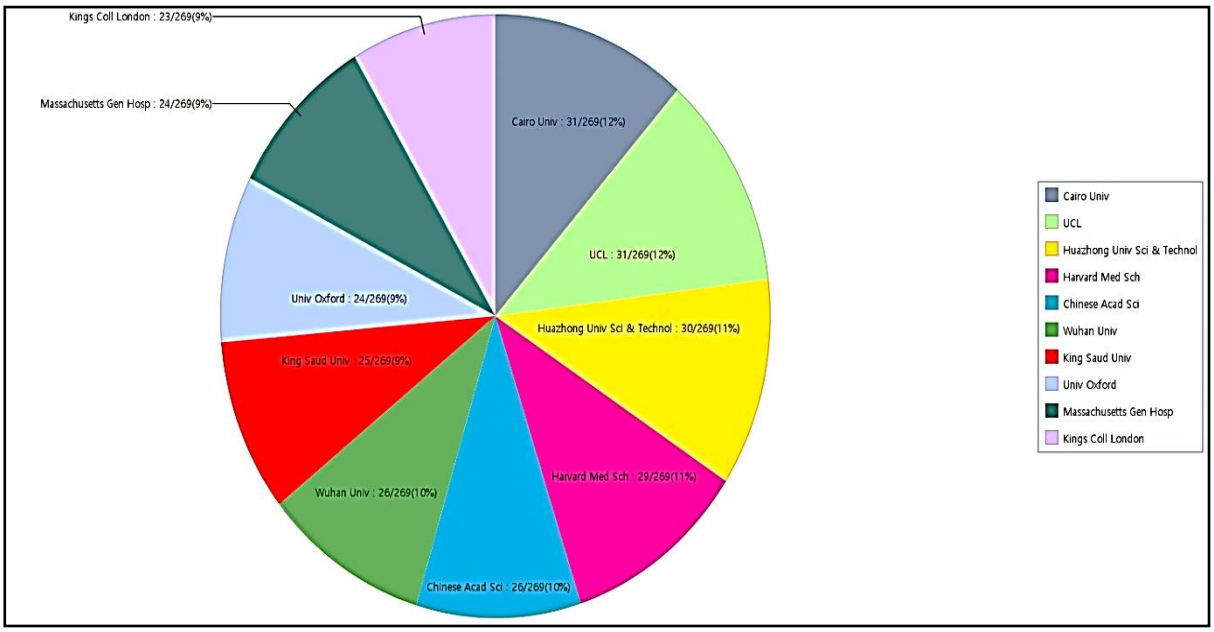

Figure (10) Top organizations in AI during COVID-19 (KnowledgeMatrix Plus outputs)

Figure 10. shows that the ten top organizations most interested in the research of Artificial Intelligence in COVID-19 based on publications and citations indicators, it appears that Cairo University is the first, then UCL after Huazhong University of Science and Technology, Harvard Medical School, Chinese Academic Science, Wuhan University, King Saud University, University of Oxford, Massachusetts General Hospital, King's College London.

4. Conclusion.

The purpose of the paper is to explain the current and new trends of research on the topic of Artificial Intelligence in COVID-19. Particular attention is paid to the bibliometric results of 1635 studies published in the Web of Science database during the last two years (2020-2021). The changing concepts adopted for classifying AI applications are organized into a standard meta-category, highlighting applications for which there is stronger evidence for the effectiveness of AI, as well as applications for which there is a limited evidence base.

Our paper presents a novel view of bibliometric analysis compared with studies completed in this area (De Felice and Polimeni, 2020; Hossain, McKyer & Ma, 2020; Naseem, 2020; Abd-Alrazaq et al., 2021; Kim et al., 2021). Especially with the use of two software, namely CiteSpace, VOSviewer, and KnowledgeMatrix Plus. This is an innovative software to present this domain.

It shows that the results of the study are in good agreement with other studies which present keywords, authors, countries, and organizations the most cited in studies of Artificial Intelligence in COVID-19. The most frequent keywords in this area are Artificial Intelligence, Covid 19, deep learning, deep neural networks, conventional neural networks, computer-assisted diagnosis, radiography thoracic, diagnostic imaging mortality, pandemic, virus pneumonia, human, physiology, respiratory syndrome,

severe acute ... etc, and this is similar and inconsistent with his findings (Hossain, Sarwar, Mckyer, & Ma, 2020).

The most cited authors in this area are Wang J., Zhang S., Li L., Li Z., Li H., Wang L., Zhang J., Wang S., Zhang Y., Wang Y., Liu J., Yang Y., Zhang X. This is similar to (Hossain, McKyer & Ma, 2020) and varies with results of (Kim et al., 2021). The most interesting countries in Artificial Intelligence in COVID-19 are the United States, India, China, the United Kingdom, Italy, Canada, Australia, Spain, Saudi Arabia, and South Korea; this is consistent with all previously completed studies (De Felice and Polimeni, 2020; Hossain, McKyer & Ma, 2020; Abd-Alrazaq et al., 2021; Kim et al., 2021). The most cited research institutions are Biomedical Engineering & Imaging Sciences (UK), Department of Radiology (China), Department of Radiology Massachusetts (USA). This differs from the findings of previous studies lead to variations in the data, particularly since previous studies relied on other databases such as MEDLINE, PubMed, Scopus, and so on. The approaches and methods of the bibliometric study differ as well.

It is also important to note that these results are not conclusive because they relied on the data of one database Scopus and did not rely on other databases, such as Web of Science, ScienceDirect, Springer ... etc. It also adopted one method (bibliometric analysis) and neglected other methods that could be relied upon in analyzing previous studies in the field such as Meta-analysis (Raza, 2020) and systematic literature review. (Albahri et al., 2020)

On the other hand, this article shows great importance as it briefly guides researchers by defining fields of research in Artificial Intelligence in COVID-19, the most frequent keywords, the most cited authors, the most interesting countries and organizations. It also defines the areas in which practitioners, leaders, and decision-makers should be interested in developing the field of artificial intelligence.

Limitation:

The findings in this paper have certain limitations. Because our objective is to construct a view of AI's contribution to the pandemic response, we avoided reviews that focus specifically on one area of AI application. Thus, it is possible that some of the reviews that are excluded contain some helpful information about a particular use of artificial intelligence. Moreover, pre-existing studies may not adequately cover applications or approaches of artificial intelligence. Finally, as the COVID-19 epidemic proceeds, we anticipate that research trends will shift often. Additionally, because we used a recognized Web of Science (WoS) database for article retrieval and followed an approved selection process, we are certain that a substantial percentage of the targeted literature was covered and that the results accurately reflect the present status of the research.

Future scope:

We believe that a number of additional areas for research become apparent when approaching the subject from a synthesis and future prediction perspective, including meta-analysis studies to leverage

the knowledge and experience gained during Covid-19 and the development of an AI-based crisis response plan model to combat epidemics.

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Conflict of interest:

The author declares that they have no conflict of interest.

References.

- Abd-Alrazaq, A., Schneider, J., Mifsud, B., Alam, T., Househ, M., Hamdi, M., & Shah, Z. (2021). A Comprehensive Overview of the COVID-19 Literature: Machine Learning–Based Bibliometric Analysis. Journal of medical Internet research, 23(3), e23703.
- Adadi, A., Lahmer, M., & Nasiri, S. (2021). Artificial Intelligence and COVID-19: A Systematic umbrella review and roads ahead. Journal of King Saud University-Computer and Information Sciences.
- Agrawal, R., Taylor, Group, F., Chatterjee, J. M., Kumar, A., Rathore, P. S., & Le, D. N. (2020). *Machine Learning for Healthcare: Handling and Managing Data*: Taylor & Francis Limited.
- Aizenberg, I., Aizenberg, N. N., & Vandewalle, J. P. (2013). *Multi-valued and universal binary neurons: theory, learning, and applications*: Springer Science & Business Media.
- Albahri, O. S., Zaidan, A. A., Albahri, A. S., Zaidan, B. B., Abdulkareem, K. H., Al-Qaysi, Z. T.,... & Rashid, N. A. (2020). A systematic review of artificial intelligence techniques in the detection and classification of COVID-19 medical images in terms of evaluation and benchmarking: Taxonomy analysis, challenges, future solutions, and methodological aspects. Journal of infection and public health.
- Baldi, P. (2018). Deep learning in biomedical data science. *Annual review of biomedical data science, 1*, 181-205.
- Basiri, M. E., Abdar, M., Cifci, M. A., Nemati, S., & Acharya, U. R. (2020). A novel method for sentiment classification of drug reviews using fusion of deep and machine learning techniques. *Knowledge-Based Systems*, 105949.
- Beam, A. L., & Kohane, I. S. (2018). Big data and machine learning in health care. *Jama, 319*(13), 1317-1318.
- Bohr, A., & Memarzadeh, K. (2020). *Artificial Intelligence in Healthcare*: Elsevier Science.
- Bote-Curiel, L., Munoz-Romero, S., Gerrero-Curieses, A., & Rojo-Álvarez, J. L. (2019). Deep learning and big data in Healthcare: A double review for critical beginners. *Applied Sciences, 9*(11), 2331.

- Catania, L. J. (2020). *Foundations of Artificial Intelligence in Healthcare and Bioscience: A User-Friendly Guide for IT Professionals, Healthcare Providers, Researchers, and Clinicians*: Elsevier Science.
- Chen, C. (2016). CiteSpace: a practical guide for mapping scientific literature (pp. 41-44). Hauppauge, NY: Nova Science Publishers.
- Chen, Y. W., & Jain, L. C. (2019). *Deep Learning in Healthcare: Paradigms and Applications*: Springer International Publishing.
- Cheon, S., Kim, J., & Lim, J. (2019). The use of deep learning to predict stroke patient mortality. *International journal of environmental research and public health, 16*(11), 1876.
- Dash, S., Acharya, B. R., Mittal, M., Abraham, A., & Kelemen, A. (2019). *Deep Learning Techniques for Biomedical and Health Informatics*: Springer International Publishing.
- Davis, R. (2020). "Integrating Digital Technologies and Data-driven Telemedicine into Smart Healthcare during the COVID-19 Pandemic," American Journal of Medical Research 7(2): 22–28. doi:10.22381/AJMR7220203
- De Felice, F., & Polimeni, A. (2020). Coronavirus Disease (COVID-19): A Machine learning bibliometric analysis. *in vivo, 34*(3 suppl), 1613-1617.
- Dechter, R. (1986). Learning while searching in constraint-satisfaction problems.
- Dobson-Lohman, E., and Potcovaru, A.-M. (2020). "Fake News Content Shaping the COVID-19 pandemic Fear: Virus Anxiety, Emotional Contagion, and Responsible Media Reporting," Analysis and Metaphysics 19: 94–100. doi:10.22381/AM19202011
- Durana, P., Valaskova, K., Vagner, L., Zadnanova, S., Podhorska, I. & Siekelova, A. (2020).Disclosure of Strategic Managers' Factotum: Behavioral Incentives of Innovative Business. International Journal of Financial Studies, 8(1), 17. https://doi.org/10.3390/ijfs810017
- Eastman, E. M. (2019). *Deep learning models for the perception of human social interactions.* Massachusetts Institute of Technology.
- Faes, L., Wagner, S. K., Fu, D. J., Liu, X., Korot, E., Ledsam, J. R.,... Kern, C. (2019). Automated deep learning design for medical image classification by health-care professionals with no coding experience: a feasibility study. *The Lancet Digital Health, 1*(5), e232-e242.
- Faust, O., Hagiwara, Y., Hong, T. J., Lih, O. S., & Acharya, U. R. (2018). Deep learning for healthcare applications based on physiological signals: A review. *Computer methods and programs in biomedicine, 161*, 1-13.
- Georgescu, A. L., Koehler, J. C., Weiske, J., Vogeley, K., Koutsouleris, N., & Falter-Wagner, C. (2020). Machine Learning to Study Social Interaction Difficulties in ASD. *Computational Approaches for Human-Human and Human-Robot Social Interactions*.

- Guo, X., Polanía, L. F., Garcia-Frias, J., & Barner, K. E. (2019). *Social relationship recognition based on a hybrid deep neural network.* Paper presented at the 2019 14th IEEE International Conference on Automatic Face & Gesture Recognition (FG 2019).
- Hossain, M. M., McKyer, E. L. J., & Ma, P. (2020). Applications of artificial intelligence technologies on mental health research during COVID-19. https://doi.org/10.31235/osf.io/w6c9b.
- Hossain, M.M., Sarwar, S.A., Mckyer, E.L.J., Ma, P., 2020. Applications of Artificial Intelligence Technologies in COVID-19 Research: A Bibliometric Study. *Preprints 2020, 2020060161*. doi:10.20944/preprints202006.0161.v1
- Institute of Science and Technology Information (KISTI).
- Jain, V., & Chatterjee, J. M. (2020). *Machine Learning with Health Care Perspective: Machine Learning and Healthcare*: Springer International Publishing.
- Khan, M., Mehran, M. T., Haq, Z. U., Ullah, Z., & Naqvi, S. R. (2021). Applications of artificial intelligence in COVID-19 pandemic: A comprehensive review. Expert Systems with Applications, 115695.
- Kim, J., Lee, D., & Park, E. (2021). Machine Learning for Mental Health in Social Media: Bibliometric Study. *Journal of Medical Internet Research*, 23(3), e24870.
- KISTI. (2016). *KnowledgeMatrix Plus ver.0.80 for supporting Scientometric Network Analysis*: Department of Scientometric Research, Korea
- Kwon, J.-m., Cho, Y., Jeon, K.-H., Cho, S., Kim, K.-H., Baek, S. D.,... Oh, B.-H. (2020). A deep learning algorithm to detect anemia with ECGs: a retrospective, multicentre study. *The Lancet Digital Health, 2*(7), e358-e367.
- Lancet, T. (2017). *Artificial Intelligence in Healthcare: Within Touching Distance*: Elsevier.
- Lawry, T. (2020). *Artificial Intelligence in Healthcare: A Leader's Guide to Winning in the New Age of Intelligent Health Systems*: Taylor & Francis.
- Lee, Y., Kwon, J.-m., Lee, Y., Park, H., Cho, H., & Park, J. (2018). Deep learning in the medical domain: predicting cardiac arrest using deep learning. *Acute and critical care, 33*(3), 117.
- Liu, X., Faes, L., Kale, A. U., Wagner, S. K., Fu, D. J., Bruynseels, A.,... Kern, C. (2019). A comparison of deep learning performance against health-care professionals in detecting diseases from medical imaging: a systematic review and meta-analysis. *The Lancet Digital Health, 1*(6), e271-e297.
- Lyons, N., and Lăzăroiu, G. (2020). "Addressing the COVID-19 Crisis by Harnessing the Internet of Things Sensors and Machine Learning Algorithms in Data-driven Smart Sustainable Cities,"Geopolitics, History, and International Relations 12(2): 65—71. doi:10.22381/GHIR12220209
- Mahajan, P. S. (2018). *Artificial Intelligence in Healthcare*: HARPERCOLLINS 360.

- Miotto, R., Wang, F., Wang, S., Jiang, X., & Dudley, J. T. (2018). Deep learning for Healthcare: review, opportunities and challenges. *Briefings in bioinformatics, 19*(6), 1236-1246.
- Mohanty, S. N., Nalinipriya, G., Jena, O. P., & Sarkar, A. (2021). *Machine Learning for Healthcare Applications*: Wiley.
- Muniasamy, A., Tabassam, S., Hussain, M., Sultana, H., Muniasamy, V., & Bhatnagar, R. (2019). *Deep Learning for Predictive Analytics in Healthcare.* The International Conference on Advanced Machine Learning Technologies and Applications (AMLTA2019): Springer International Publishing.
- Naseem, M., Akhund, R., Arshad, H., & Ibrahim, M. T. (2020). Exploring the Potential of Artificial Intelligence and Machine Learning to Combat COVID-19 and Existing Opportunities for LMIC: A Scoping Review. Journal of Primary Care & Community Health, 11, 2150132720963634.
- Ngiam, K. Y., & Khor, W. (2019). Big data and machine learning algorithms for health-care delivery. *The Lancet Oncology, 20*(5), e262-e273.
- Nordlinger, B., Villani, C., & Rus, D. (2020). *Healthcare and Artificial Intelligence*: Springer International Publishing.
- Panesar, A. (2019). *Machine Learning and AI for Healthcare: Big Data for Improved Health Outcomes*: Apress.
- Purushotham, S., Meng, C., Che, Z., & Liu, Y. (2018). Benchmarking deep learning models on large healthcare datasets. *Journal of biomedical informatics, 83*, 112-134.
- Rafailidis, D., & Crestani, F. (2017). *Recommendation with social relationships via deep learning.* Paper presented at the Proceedings of the ACM SIGIR International Conference on Theory of Information Retrieval.
- Ravì, D., Wong, C., Deligianni, F., Berthelot, M., Andreu-Perez, J., Lo, B., & Yang, G.-Z. (2016). Deep learning for health informatics. *IEEE journal of biomedical and health informatics, 21*(1), 4-21.
- Raza, K. (2020). Artificial intelligence against COVID-19: A meta-analysis of current research. Big *Data Analytics and Artificial Intelligence Against COVID-19: Innovation Vision and Approach*, 165-176.
- Saba, L., Biswas, M., Kuppili, V., Godia, E. C., Suri, H. S., Edla, D. R.,... Mavrogeni, S. (2019). The present and future of deep learning in radiology. *European journal of radiology, 114*, 14-24.
- Santosh, K. C., Das, N., & Ghosh, S. (2021). *Deep Learning Models for Medical Imaging*: Elsevier Science.
- Sisodia, D. S., Pachori, R. B., & Garg, L. (2020). *Advancement of Artificial Intelligence in Healthcare Engineering*: Medical Information Science Reference.
- Van Eck, N. J., & Waltman, L. (2013). VOSviewer manual. *Leiden: Univeristeit Leiden, 1*(1), 1-53.
- Yang, H.-C., Islam, M. M., & Li, Y.-C. (2018). Potentiality of deep learning application in Healthcare. *Comput. Methods Programs Biomed., 161*, 1.

- Yazhini, K., & Loganathan, D. (2019). *A state of art approaches on deep learning models in Healthcare: An application perspective.* Paper presented at the 2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI).
- Yoon, H. (2018). *New Statistical Transfer Learning Models for Health Care Applications*: Arizona State University.
- Yu, Y., Li, M., Liu, L., Li, Y., & Wang, J. (2019). Clinical big data and deep learning: Applications, challenges, and future outlooks. *Big Data Mining and Analytics, 2*(4), 288-305.
- Zhang, L., Huang, J., & Liu, L. (2019). Improved deep learning network based in combination with cost-sensitive learning for early detection of ovarian cancer in color ultrasound detecting system. *Journal of medical systems, 43*(8), 251.
- Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods, 18*(3), 429-472.

Appendices

Appendix 1

Most Citing Articles/Keywords

Age	Global Citation Scores	Local Citation Scores	Bibliography
5	893	0	ZIEGLER, CGK (2020.0) Sars-cov-2 receptor ace2 is an interferon-stimulated gene in human airway epithelial cells and is detected in specific cell subsets across tissues. CELL, V181, P39 DOI 10.1016/j.cell.2020.04.035
2	675	0	BI, QF (2020.0) Epidemiology and transmission of covid-19 in 391 cases and 1286 of their close contacts in shenzhen, china: a retrospective cohort study. LANCET INFECTIOUS DISEASES DOI 10.1016/S1473-3099(20)30287-5
2	484	0	OZTURK, T (2020.0) Automated detection of covid-19 cases using deep neural networks with x-ray images. COMPUTERS IN BIOLOGY AND MEDICINE DOI 10.1016/j.compbiomed.2020.103792
1	484	0	OZTURK, T (2020.0) Automated detection of covid-19 cases using deep neural networks with x-ray images. COMPUTERS IN BIOLOGY AND MEDICINE DOI 10.1016/j.compbiomed.2020.103792
4	174	0	ARDAKANI, AA (2020.0) Application of deep learning technique to manage covid-19 in routine clinical practice using ct images: results of 10 convolutional neural networks. COMPUTERS IN BIOLOGY AND MEDICINE DOI 10.1016/j.compbiomed.2020.103795
5	156	0	CHOWDHURY, MEH (2020.0) Can ai help in screening viral and covid-19 pneumonia?. IEEE ACCESS DOI 10.1109/ACCESS.2020.3010287
4	144	0	FAN, DP (2020.0) Inf-net: automatic covid-19 lung infection segmentation from ct

Age	Global Citation Scores	Local Citation Scores	Bibliography
			images. IEEE TRANSACTIONS ON MEDICAL IMAGING, V39, P12 DOI 10.1109/TMI.2020.2996645
5	140	0	OH, Y (2020.0) Deep learning covid-19 features on cxr using limited training data sets. IEEE TRANSACTIONS ON MEDICAL IMAGING, V39, P13 DOI 10.1109/TMI.2020.2993291
2	120	0	ZENG, ZJ (2020.0) From high-touch to high-tech: covid-19 drives robotics adoption. TOURISM GEOGRAPHIES, V22, P11 DOI 10.1080/14616688.2020.1762118
4	110	0	WAHEED, A (2020.0) Covidgan: data augmentation using auxiliary classifier gan for improved covid-19 detection. IEEE ACCESS DOI 10.1109/ACCESS.2020.2994762
6	108	0	LOEY, M (2020.0) Within the lack of chest covid-19 x-ray dataset: a novel detection model based on gan and deep transfer learning. SYMMETRY-BASEL DOI 10.3390/sym12040651
4	108	0	LOEY, M (2020.0) Within the lack of chest covid-19 x-ray dataset: a novel detection model based on gan and deep transfer learning. SYMMETRY-BASEL DOI 10.3390/sym12040651
2	108	0	LOEY, M (2020.0) Within the lack of chest covid-19 x-ray dataset: a novel detection model based on gan and deep transfer learning. SYMMETRY-BASEL DOI 10.3390/sym12040651
5	103	0	BRUNESE, L (2020.0) Explainable deep learning for pulmonary disease and coronavirus covid-19 detection from x-rays. COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE DOI 10.1016/j.cmpb.2020.105608
2	99	0	CUI, FY (2020.0) Diagnostic methods and potential portable biosensors for coronavirus disease 2019. BIOSENSORS & BIOELECTRONICS DOI 10.1016/j.bios.2020.112349

Appendix 2

The most frequently keywords in Artificial Intelligence during COVID-19

Frequence	Correlations	Keyword
405	16	Artificial Intelligence
196	29	Deep Learning
165	29	Machine Learning
51	24	Big Data
46	29	Computed Tomography
42	20	Convolutional Neural Network
35	15	Chest X-Ray
28	14	Transfer Learning
26	13	Neural Network
26	7	Covid-19 Pandemic

Frequence	Correlations	Keyword
26	10	Public Health
25	28	Feature Extraction
21	18	Internet Of Thing
17	16	Digital Health
16	10	Chest Ct
15	24	X-Ray Imaging
15	12	Mathematical Model
14	8	Mental Health
14	5	Artificial Neural Network
13	7	Feature Selection
13	19	Predictive Model
13	5	Social Media
13	7	Infectious Disease
13	6	Coronavirus Disease 2019
12	8	Coronavirus Disease
11	9	Social Distancing
10	11	Medical Service
10	3	Natural Language Processing

Appendix 3

The most cited authors in Artificial Intelligence during COVID-19

Author	Documents	Citations	Total Link Strength
Yang, Z	7	2542	245
Xia, L	7	2489	254
Chen, C	6	2482	176
Zhang, Z	13	889	118
Zhang, J	19	881	120
Zhang, T	5	852	55
Liu, X	13	732	43
Wu, Y	6	718	29
Sun, Y	8	716	77
Acharya, Ur	5	687	110
Wang, L	16	684	179
Li, L	12	632	301
Ourselin, S	10	595	273
Steves, Cj	10	595	273
Sudre, Ch	8	578	256
Wolf, J	9	571	257
Spector, Td	8	569	244

Author	Documents	Citations	Total Link Strength
Chan, At	7	535	231
Drew, Da	6	535	215
Nguyen, Lh	6	535	215
Li, Y	14	500	217
Wang, X	19	493	227
Wang, J	14	482	135
Wang, G	5	437	216
Xu, Z	5	418	238
Xu, R	7	405	26
Zhang, S	9	391	266
Yang, J	10	309	75
Wang, Q	10	292	80
Wang, S	9	281	99
Chen, Y	13	266	107
Ma, J	7	266	125
Li, X	18	263	141
Wu, W	5	260	66
Xu, J	8	257	32
Khalifa, Nem	7	252	54
Loey, M	8	252	57
Javaid, M	5	251	35
Liu, J	16	232	172
Al-Turjman, F	15	217	116
Chen, J	9	213	57
Zhang, X	19	209	175
Zhang, Y	15	206	99

Appendix 4

The most interesting countries in Artificial Intelligence during COVID-19

Country	Documents	Citations	Total Link Strength
Peoples R China	317	8484	2148
USA	401	7466	1817
England	192	4407	980
Netherlands	25	2712	440
India	208	1522	1322
Australia	97	1336	720
Germany	66	1286	259
France	47	1236	111
Italy	109	1023	619

Country	Documents	Citations	Total Link Strength
Taiwan	42	1012	515
South Africa	20	1002	89
Turkey	54	993	614
Canada	86	988	652
Singapore	33	922	390
South Korea	89	817	698
Egypt	75	654	446
Japan	28	650	325
Iran	41	592	370
Saudi Arabia	117	545	624

Appendix 5

The most interesting organizations in Artificial Intelligence during COVID-19

Organization	Documents	Citations	Total link strength
Huazhong Univ Sci & Technol	29	3106	428
Massachusetts Gen Hosp	22	1460	319
Kings Coll London	22	1238	175
Harvard Med Sch	27	1194	203
Univ Hong Kong	20	1054	81
Zoe Global	6	1025	120
Asia Univ	18	840	285
Univ Cambridge	16	730	96
Ngee Ann Polytech	5	687	192
Univ Bristol	8	684	151
Wuhan Univ	26	658	245
Zhejiang Univ	19	515	215
Minist Hlth	5	490	119
Brigham & Womens Hosp	7	485	72
Univ Waterloo	8	463	189
Cairo Univ	31	447	176
Univ Oxford	21	436	75
Case Western Reserve Univ	12	430	25
Guangzhou Med Univ	5	426	87
Wuhan Univ Sci & Technol	6	425	83
Shenzhen Univ	11	422	233
Harvard Th Chan Sch Publ Hlth	5	404	15
Broad Inst Mit & Harvard	6	387	15
Chinese Acad Sci	25	380	163
Ucl	28	380	152

Organization	Documents	Citations	Total link strength
Sun Yat Sen Univ	14	366	180
Chinese People's Liberat Army Gen Hosp	5	348	217
Xi An Jiao Tong Univ	8	340	146
Univ Chinese Acad Sci	18	320	105
Sichuan Univ	10	310	170
Harvard Univ	14	300	65