



Review

# Exploring the Major Trends and Emerging Themes of Artificial Intelligence in the Scientific Leading Journals amidst the COVID-19 Era

Mohammad Soliman <sup>1,2,\*</sup> , Tarek Fatnassi <sup>3</sup> , Islam Elgammal <sup>4,5</sup> and Ronnie Figueiredo <sup>6,7,8</sup>

- <sup>1</sup> Head of Scientific Research Department, University of Technology and Applied Sciences, Salalah P.O. Box 74, Oman
  - <sup>2</sup> Faculty of Tourism and Hotels, Fayoum University, Fayoum 63514, Egypt
  - <sup>3</sup> Faculty of Computer Science, College of Computing and Information Sciences, University of Technology and Applied Sciences, Salalah P.O. Box 74, Oman
  - <sup>4</sup> Business Administration Department, College of Business, University of Jeddah, Jeddah 23218, Saudi Arabia
  - <sup>5</sup> Tourism Studies Department, Faculty of Tourism, Suez Canal University, The Ring Road, Ismailia 41522, Egypt
  - <sup>6</sup> Centre of Applied Research in Management and Economics (CARME), School of Technology and Management (ESTG), Polytechnic of Leiria, 2411-901 Leiria, Portugal
  - <sup>7</sup> Research Center in Business Sciences (NECE), University of Beira Interior (UBI), 6201-001 Covilhã, Portugal
  - <sup>8</sup> Spinner Innovation Centre (SIC), 2840-626 Lisbon, Portugal
- \* Correspondence: msoliman.sal@cas.edu.om

**Abstract:** Artificial intelligence (AI) has recently become the focus of academia and practitioners, reflecting the substantial evolution of scientific production in this area, particularly during the COVID-19 era. However, there is no known academic work exploring the major trends and the extant and emerging themes of scientific research production of AI leading journals. To this end, this study is to specify the research progress on AI among the top-tier journals by highlighting the development of its trends, topics, and key themes. This article employs an integrated bibliometric analysis using evaluative and relational metrics to analyze, map, and outline the key trends and themes of articles published in the leading AI academic journals, based on the latest CiteScore of Scopus-indexed journals between 2020 and 2021. The findings depict the major trends, conceptual and social structures, and key themes of AI leading journals' publications during the given period. This paper represents valuable implications for concerned scholars, research centers, higher education institutions, and various organizations within different domains. Limitations and directions for further research are outlined.

**Keywords:** artificial intelligence (AI); COVID-19; AI leading journals; bibliometric analysis; visualization; Scopus



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## 1. Introduction

In present times, the digital era relies heavily on the use of Artificial Intelligence (AI), which plays a significant role in various research areas. AI is a discipline that focuses on how to make computers simulate people's thinking and intelligent behavior by training models on huge amounts of data using machine and deep learning techniques [1]. The intensive adoption of artificial intelligence techniques in most fields is explained by the fact that it improves their efficiencies and enhances human capabilities. Recent studies have shown that the deployment of artificial intelligence in many areas was fruitful and led to great success. These sectors include healthcare, education (Natural Language Processing), self-driving drones and vehicles, E-commerce, AI home-driven applications, finance, and so on [2].

During the last two years, the globe witnessed the emergence of a contagious and dangerous disease called COVID-19 which causes 18.2 million deaths across the world

between 2020 and 2021 [3]. This pandemic has disturbed and paralyzed all the activities of our daily life including education, transportation, travel, health care, and so on [4]. This is a novel virus and researchers in this field could not confront it and stop the spread of the pandemic because they did not have enough knowledge of its characteristics and its behavior [5].

This critical situation urged researchers to mobilize to investigate various aspects of the virus such as how it evolved, its effects, its vaccinations, and so on. This mobilization is characterized by the intensive focus of research work on Artificial intelligence, which is adopted by industries as a weapon to combat the COVID-19 pandemic [6]. Indeed, AI is one of the technologies that played a crucial role in alleviating the intensity of the pandemic. This technology provides plenty of useful techniques for the detection, diagnosis, screening, classification, prediction, and forecast of the virus [7,8]. Furthermore, these techniques are very helpful to limit the spread of the disease by tracing contact, monitoring quarantine, the analysis of trends, the analysis and reporting the COVID-19 symptoms, estimating the severity of the symptoms, modeling intelligently the spread of the disease, and so on [2].

Consequently, this triggered researchers throughout the world to study the applications of AI to healthcare and other sectors, the impact and efficiency of AI-based solutions, and how these solutions contribute to the alleviation of pandemic consequences. This led to the rise of scientific publications in AI journals. For example, Guo et al. looked at AI in the Health Care context by using bibliometric analysis [9]. They retrieved AI English articles published up to December 2019 with the use of HistCite software to identify the main health problems that can be investigated through the development of AI studies (i.e., cancer, heart failure, and depression). Similarly, Romero-Riaño et al. adopted the bibliometric analysis to investigate the AI theory trends and development during two different periods, 2010–2014 and 2015–2019, and reported that AI is considered an active field of research that is growing rapidly in recent years [10]. Other studies utilized bibliometric analysis to look at AI in government and policymaking studies with the use of NVivo 12 Plus and VOSviewer [11], AI in e-Learning using VOSviewer through WOS data [12], and AI in Education to highlight major trends such as machine learning and intelligent tutoring systems [13].

In this context, our study aims to identify the major AI trends and themes that are covered in most of the research works, analyze the findings using a bibliometric approach, and provide a clear overview of the major role AI has played in many sectors during the pandemic time. In other words, the main objective of this work is to find out the major trends and key themes of AI leading journals between 2020 and 2021. First, we conducted a systematic search for the literature that is related to COVID-19 and the efficient AI applications that fight against the pandemic. We explored only the relevant research works that are published in AI journals. Then, a bibliometric analysis of the literature was conducted on the explored studies to find out the research trends and themes, prominent topics, and the overall collaboration in the area of AI on COVID-19. Such analysis is very helpful in monitoring the patterns and the trends of the literature in many areas including healthcare and education. It explores many important indicators, which include annual productions, leading contributors (author's institutions, countries), the most productive journals, the most cited articles, co-authorship, co-citation and co-occurrence analysis, and the key research topics and themes [14].

Such work is very challenging and important. Its importance can be explained by the fact that this is the first work that provides a clear picture of the major AI-based efforts throughout the globe that target COVID-19. In addition, it provides a quantitative analysis concerning the applications of AI techniques in most sectors to mitigate the crisis caused by the pandemic. One more reason that explains the importance of this study is its originality. Indeed, it comes to filling a gap related to the absence in the literature review of a deep and extensive bibliometric analysis that aims to explore the significant trends as well as the major emerging avenues of the scientific publication of the leading AI journals. Therefore, this research work would be beneficial for the scientific research that focuses on AI and

COVID-19 by contributing to giving a comprehensive direction for future research works in this field.

The organization of the rest of the paper is as follows. Section 2 presents the relevant literature review that focuses on AI and COVID-19. Section 3 discusses research methods and strategies for search and screening. Section 4 introduces the bibliometric analysis and summarizes the major results. In Section 5, the findings of the analysis will be discussed. Section 6 will be devoted to the discussion of the theoretical and practical implications. Finally, the limitations of this work along with the future research avenues will be highlighted.

## 2. Literature Review

AI is a computer engineering field that tends to make intelligent machines, notably, intelligent software. It provides advanced techniques that leverage machines and computers to mimic the human mind in terms of solving problems. Consequently, AI allows the creation of smart computer programs able to handle a lot of tasks such as analyzing astronomically huge datasets to retrieve useful insights, recommending a suitable video from a large dataset of videos, controlling traffic, etc. AI-based technologies achieved great success and have become an essential part of our personal and public decision-making [15].

Therefore, the applications of AI in many sectors has been increased rapidly to mainly reveal hidden knowledge from big data and enhance the decision-making process. Among the fields that witness growth and effectiveness after the application of AI techniques, we can mention e-learning (Intelligent Tutoring System), manufacturing and factory automation, cybersecurity and digital forensics, human resource management, AI-driven home automation, hazardous environments, military application, finance, AI-based healthcare applications, robotics, and so on [15]. The research work of Thakur et al., showed also the significance of applying AI in sentiment analysis by extracting insight from 12,028 tweets about the Omicron variant [16].

The great potential of AI has been demonstrated especially during the crisis of the COVID-19 pandemic that hit the globe over the last two years [17]. This pandemic has dramatically disrupted our lives by forcing a lot of restrictions. These restrictions include the closure of cities and borders, changes in working hours, and operating procedures in most companies and organizations. All sectors have been affected badly including transportation, business, education, healthcare, and travel. In such a situation, AI has been adopted rapidly to combat the pandemic [5]. In this context, several research works have covered the role of AI to alleviate the impact of the COVID-19 crisis in many sectors.

In previous research, scholars highlighted the role AI has played in combating the pandemic in the healthcare sector [18]. They mentioned that several AI-based technologies have been invented during this crisis to assist in many tasks. These tasks include the early detection and diagnosis of the virus, the analysis of the trends, and the mitigation of the overall situation in the healthcare sector. AI-based programs can enhance the forecasting precision and thus additional help can be provided to the people who are vulnerable along with the proper treatment that can be provided regularly. As a result, the mortality rate has been reduced. In addition to that, AI showed its efficacy in the health sector during the COVID-19 era as it limits the spread of the pandemic. Scholars concisely listed the contributions of AI in the healthcare sector as follows: early detection and diagnosis of infection, monitoring treatments, tracing the contact of individuals, projection of cases and mortality, development of drugs and vaccines, reducing the workload of healthcare workers, and prevention of the disease. The tools of AI were also involved in the development of drugs, the forecast of the disease's spread, and the surveillance of the population. Further, the authors discussed the challenges researchers may face when they apply AI to datasets in terms of the privacy and security of data. Pantelimon et al. recent study underlined the impact of the COVID-19 pandemic on the education sector [19]. The educational system has been changed from face-to-face to fully online because the pandemic caused the closure of educational institutions to avoid the spread of the virus. Furthermore, they

emphasized the importance of online learning in such conditions. This study demonstrates the crucial role of AI in enhancing e-learning and adapting it to the need of the sector. The application of AI in the E-learning system gives birth to adaptive learning systems that can fit the individual needs of teachers and students. In addition, they stressed the efficacy of AI-driven E-learning platforms to transcend the crisis in the educational field. In Piccialli et al. recent study, the vital role AI played in the dramatic acceleration of digital transformation in many sectors to tackle the challenges imposed by the COVID-19 pandemic was confirmed [20]. The authors focused mainly on the AI-based technologies that give support to healthcare, society, and research. These technologies include advanced models for the diagnosis of pneumonia, the detection of whether people wear masks or not, the recognition of environments, the control of people's movement and analysis of their displacement, the automation of disinfection robots, the recognition of cough sound, protein folding, reviewing the literature review of the COVID-19 using text mining, finding out associations and the prediction of the interaction between drug and disease and thus invent antiviral drugs. The success of these technologies in facing the crisis explains the strength of the two AI methods which are Machine learning (ML) and Deep Learning (DL). Moreover, Mhlanga discussed the dramatic impact of the pandemic on the economies of the world and the health sector [21]. This work assessed the role of AI in machine learning in fighting against the pandemic. After conducting qualitative content analysis, the author stressed the vital role AI and machine learning played in finding solutions for most of the challenges the pandemic imposes. These solutions contributed mainly to controlling the spread of the virus, speeding up research on COVID-19 trends. Further, the author raised a call to governments to build trust in AI and machine learning and develop AI-based technologies to guarantee the achievement of the goals related to the sustainable development of health and wellbeing. Additionally, Rahman et al., study provided a comprehensive exploration of the major AI approaches and the aspects of AI-based technologies, and their implications for mitigating the catastrophic effects of the COVID-19 crisis on the healthcare sector and society [22]. The major AI applications that are highlighted in this study include the diagnosis and the detection of the virus, the analysis of data and procedures of treatments, the development of drugs, control of society and its services along with the prediction of the pandemic's progress.

Few studies employed bibliometric analysis while reviewing the publications that cover AI during the COVID-19 pandemic. Islam et al., provided a comprehensive overview of the publications that were related to the applications of AI during the COVID-19 pandemic [23]. They conducted a longitudinal bibliometric analysis on 729 research papers that are published between 2020 and 2021 on the web of science. This is a quantitative analysis of the retrieved literature to find out the trends and relevant patterns based on the following parameters: country, research area, source, author, institutions, citations, co-citations, and keywords. The major findings of this analysis consist of citing the main applications of AI during the pandemic which include the diagnosis and detection of COVID-19, the trends of the epidemic, classification and repurposing of drugs, patients screening, and early treatments. Furthermore, it was found that researchers from the USA, China, Italy, and Spain conducted the highest number of publications related to AI and COVID-19. The authors of [24] conducted a bibliometric study on 105 research works obtained from the MEDLINE database to assess the current trends and outstanding research domains related to the use of AI amid the COVID-19 outbreak. The main finding of this analysis indicated that USA and China are the leaders in terms of research publications in this field. Furthermore, the outcome of the study highlights the major topics covered in these publications. These topics include control and prevention, epidemiological characteristics, diagnostics, therapeutics, psychological conditions, and several data sciences fields that are related to COVID-19. Moreover, this work stressed the importance of considering several aspects while developing AI-powered technologies. These aspects include health disparities, socio-legal issues, vaccine development, and applied public health. Tasdelen and Ugur conducted a bibliometric analysis of the AI literature during COVID-19 to help researchers

in this field easily find the latest avenues regarding AI research and its contributions during the pandemic [25]. This analysis was conducted based on some indicators, which include the authors' h-index and the impact factors of the publications.

Overall, bibliometric analysis works of the literature that covers AI and COVID-19 are few. Even the abovementioned bibliometric studies do not give a comprehensive examination of the actual AI and COVID-19 literature because the number of articles they covered is limited to 700 papers and they conducted the analysis based on a few indicators [18]. To fill this gap, the main objective of our work is to conduct a deep bibliometric analysis using a lot of comprehensive parameters on a huge number of articles to find out all the trends, themes, and research avenues of the scientific publications in leading AI journals amid the pandemic.

### 3. Research Methods

#### 3.1. Approach and Procedures

According to Koseoglu et al., bibliometric studies could be classified into three methods, including (a) evaluative techniques, (b) relational measures, and (c) review studies [26]. The approaches of evaluative and relational measures [27] were employed in this work. Evaluative methods consist of three prime metrics; namely productivity, impact, and hybrid metrics [28]. The present work employed productivity and impact measures to provide a broad picture and in-depth overview of the evolution and major trends associated with the AI leading journals during the given period. These involve some metrics such as annual production, most productive scholars, countries and institutions, the greatest cited documents, etc. Moreover, these measures were analyzed using the Scopus Tools Analysis, along with some interventions by the authors using Microsoft Excel. It should be considered that these metrics are widely used by researchers in different settings (e.g., [21,29,30]) including academic journals belonging to different areas [31–33].

In addition, the present work utilizes relational-related techniques to visually map the academic production of high-rank AI journals. These include co-authorship analysis and co-word analysis (see [25]). Co-author analysis is employed to evaluate the social structure, whereas co-word analysis is utilized to establish the conceptual structure of the big data produced by AI leading academic journals during the COVID-19 era (2020–2021). The software of VOSviewer [34] was used to conduct relational-associated techniques, which are employed in several past studies within different contexts (see, e.g., [27]).

#### 3.2. Data Collection

Based on the latest Scopus CiteScore-2020 announced in the mid of 2021, this research concentrates on the top-tier ten journals in the "Artificial Intelligence" category, belonging under the area of "Computer Science". Table 1 shows the leading AI journals according to Scopus-CiteScore-2020.

**Table 1.** The leading AI academic journals based on Scopus-CiteScore-2020.

R *	Journal Title	JTA *	CiteScore
1	IEEE Transactions on Pattern Analysis and Machine Intelligence	IEEE-TPAMI	44.2
2	Foundations and Trends in Machine Learning	FTML	37.8
3	Science Robotics	SR	25.7
4	Physics of Life Reviews	PLR	21.5
5	IEEE Transactions on Neural Networks and Learning Systems	IEEE-TNNLS	19.8
6	IEEE Transactions on Fuzzy Systems	IEEE-TFS	18.3
7	International Journal of Information Management	IJIM	18.1
8	IEEE Computational Intelligence Magazine	IEEE-CIM	16.5
9	Pattern Recognition	PR	15.7
10	International Journal of Computer Vision	IJCV	15.0

Note: \* R = Rank; JTA = Journal Title Abbreviation to be used throughout the whole manuscript.



A total of 5890 documents (all English publication types) of the top-tier 10 AI academic journals (Table 2) were gathered over two years, between 2020 and 2021. However, data collection for the current study was finalized on 17 February 2022. According to [35], scholars have recently debated the extent to which open-access journals (OA) are influencing the number of citations for certain papers since they are available for free on the web. Furthermore, citation metrics are doubtful to scholars such as in Aksnes et al. and Alperin et al. [36,37] as they claim that it may not be accurate in evaluating journal impacts since most citations in Canadian and US universities are found to be received from post-graduate students. Nevertheless, citation metrics reflect the extent to which the academic world is using the study while OA journals are allowing for broader opportunities and access for academics and practitioners to read recent articles [35].

**Table 2.** Scientific production of the leading AI academic journals during 2020 and 2021.

Journal	Number of Documents		
	2020	2021	Total
IEEE-TPAMI	300	796	1096
FTML	4	5	9
SR	87	121	208
PLR	65	72	137
IEEE-TNNLS	530	1325	1855
IEEE-TFS	330	525	855
IJIM	218	167	385
IEEE-CIM	43	44	87
PR	412	519	931
IJCV	158	169	327
Total	2147	3743	5890

In the current study, the top leading journal based on Scopus-CiteScore-2020 is the *IEEE Transactions on Pattern Analysis and Machine Intelligence*, which is an OA journal that received the highest cite score. Similarly, the second and third journals in the list are OA journals with a cite score of 37.8 and 25.7. However, the fourth journal (i.e., *Physics of Life Reviews*) offers authors two options; first, the Gold open access where the paper will be available online after paying the publication fees; and second, the subscription for certain universities or waiving partial or full fees for authors affiliated to developing countries universities [38], which is giving a chance to a variety of authors in many regions in the world to have OA publication opportunities. Further, the AI topic is receiving much attention from scholars and therefore fast publication in OA journals would help to improve the existing AI body of knowledge and improve AI understanding. Hence we believe that the leading AI academic journals based on Scopus-CiteScore-2020 are a good base for looking at the AI topic in the current study. Figure 1 summarizes the process of data collection.

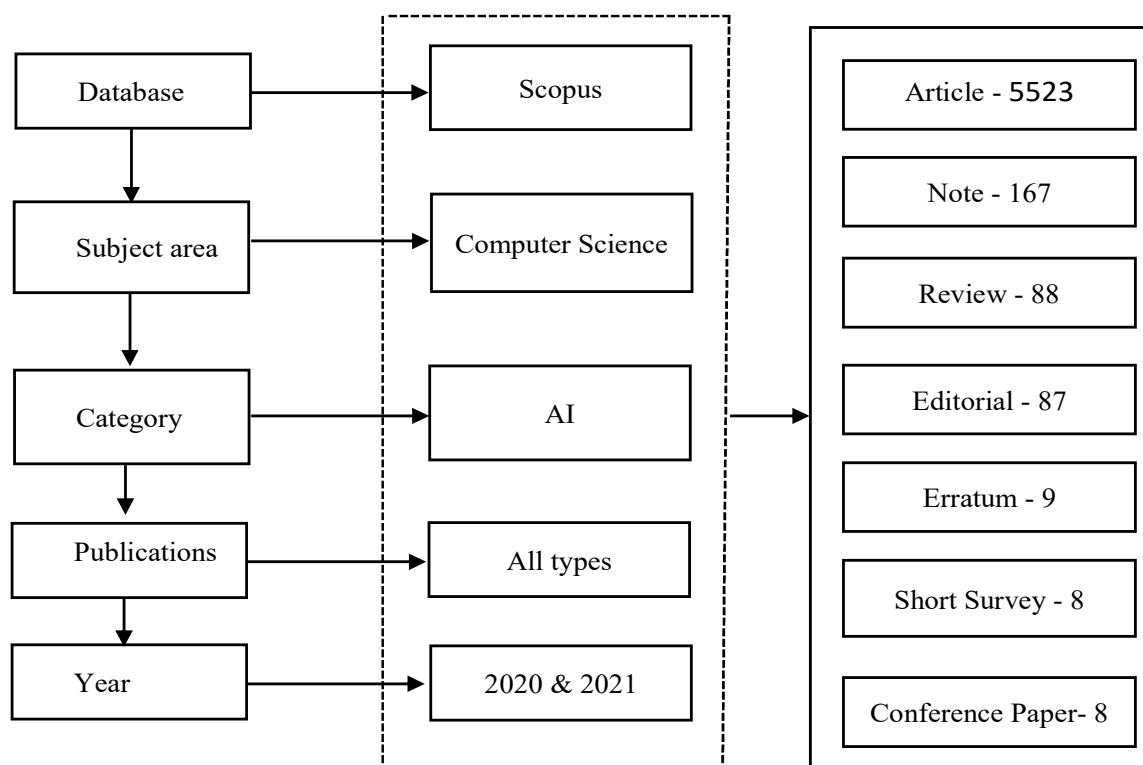


Figure 1. Data collection process.

#### 4. Findings

This section presents the results of the descriptive analysis or productivity analysis (i.e., annual production, most productive authors, countries, and organizations) and the biometric/network analysis (i.e., citation analysis, social structure (co-authorship analysis) and conceptual structure (i.e., co-occurrence/key-words analysis)) of the leading AI journals are all presented.

##### 4.1. Productivity Analysis

Table 2 reveals the number of scientific publications in the top-tier AI journals in the two selected years (2020 and 2021). It can be clearly seen that the number of all publication types of the highest rank journals of AI has witnessed a remarkable growth in the year 2021 compared to the year 2020. In addition, the peak value of publications is recorded in the journal *IEEE-TNNLS* (1855 documents). This is followed by the journals *IEEE-TPAMI* and *PR*; producing 1096 and 931 documents, respectively. The lowest figures of publications during the two chosen years are recorded amongst the journals *IEEE-CIM* and *FTML* with 87 and nine documents accordingly.

Regarding the most productive authors, Table 3 shows that Li X. published the highest number of documents (148) in the leading AI journals during 2020 and 2021. Both Wang Y. and Zhang Y. published a considerable number of documents at 144 and 143 documents, respectively.

Table 4 shows the most productive nations in the top-tier AI journals during the COVID-19 era (2020 and 2021). China has recorded the peak value (2874 documents) followed by the US, the UK, and Australia, which produced 895, 430, and 426 documents, respectively. Hong Kong and Canada produced 242 and 218 publications accordingly.

**Table 3.** Most productive authors in the leading AI journals during (2020 and 2021).

R	Author	Documents
1	Li X.	148
2	Wang Y.	144
3	Zhang Y.	143
4	Wang Z.	139
5	Liu Y.	133
6	Wang J.	131
7	Li Y.	128
8	Zhang H.	118
9	Li J.	111
10	Wang X.	107

**Table 4.** Most productive countries in the leading AI journals during (2020 and 2021).

R	Country	Documents
1	China	2874
2	United States	895
3	United Kingdom	430
4	Australia	426
5	Hong Kong	242
6	Canada	218
7	France	182
8	Germany	181
9	South Korea	169
10	Singapore	164

Table 5 points out the contributions of institutions to the highest-ranked AI journals in the COVID-19 era in 2020 and 2021. Inception Institute of Artificial Intelligence, Abu Dhabi, UAE produced 25 documents, School of Artificial Intelligence, University of Chinese Academy of Sciences, Beijing, China has 20 documents, while the University of Chinese Academy of Sciences, Beijing, China produced 19 publications.

**Table 5.** Most productive organizations in the leading AI journals during (2020 and 2021).

R	Organization	Documents
1	Inception Institute of Artificial Intelligence, Abu Dhabi, UAE	25
2	School of Artificial Intelligence, University of Chinese Academy of Sciences, Beijing, 100049, China	20
3	University of Chinese Academy of Sciences, Beijing, 100049, China	19
4	School of Computer Science and Engineering, Nanjing University of Science and Technology, Nanjing, 210094, China	16
5	University of Chinese Academy of Sciences, Beijing, China	14
6	College of Information Science and Engineering, Northeastern University, Shenyang, 110819, China"	14
7	National Tsing Hua University, Taiwan"	14
8	Navigation College, Dalian Maritime University, Dalian, 116026, China	14
9	School of Data and Computer Science, Sun Yat-Sen University, Guangzhou, 510006, China	13
10	School of Electrical and Information Engineering, Tianjin University, Tianjin, 300072, China	13

#### 4.2. Citation Analysis

Table 6 presents the most-cited documents in the leading journals of AI during the years 2020 and 2021. Overall, it can be seen that the most-cited document types are all articles. In addition, the top 10 most-cited articles in the leading AI journal have been published in the journal *IEEE-TPAMI* (five articles).



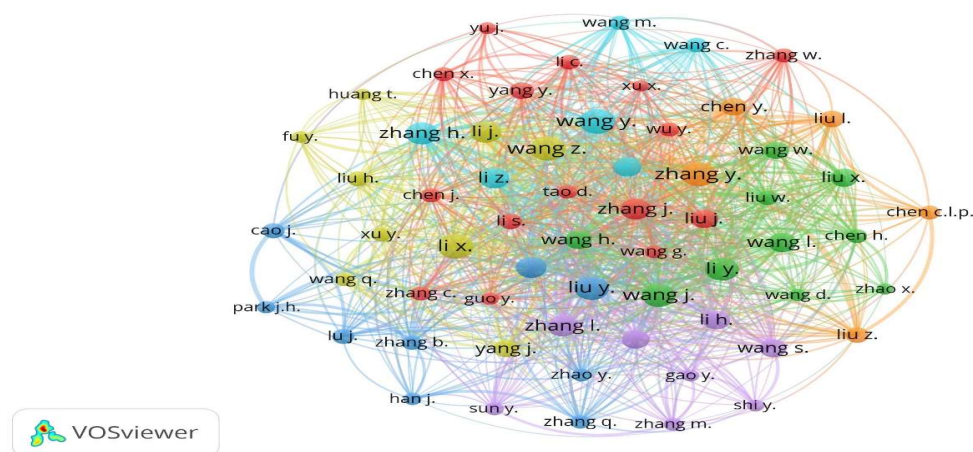
**Table 6.** Most cited documents in the leading AI journals during (2020 and 2021).

R	Authors	Title	Year	Source Title	Citation	Type
1	Lin T.-Y., et al.	Focal Loss for Dense Object Detection	2020	IEEE-TPAMI	1069	Article
2	Hu J., et al.	Squeeze-and-Excitation Networks	2020	IEEE-TPAMI	776	Article
3	He K., et al.	Mask R-CNN	2020	IEEE-TPAMI	659	Article
4	Selvaraju R.R., et al.	Grad-CAM: Visual Explanations from Deep Networks via Gradient-based Localization	2020	IJCV	560	Article
5	Liu L., et al.	Deep Learning for Generic Object Detection: A Survey	2020	IJCV	555	Article
6	Cao Z., et al.	OpenPose: Realtime Multi-Person 2D Pose Estimation Using Part Affinity Fields	2021	IEEE-TPAMI	440	Article
7	Wu Z., et al.	A Comprehensive Survey on Graph Neural Networks	2021	IEEE-TNNLS	432	Article
8	Dwivedi Y.K., et al.	Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy	2021	IJIM	273	Article
9	Gao S.-H., et al.	Res2Net: A New Multi-Scale Backbone Architecture	2021	IEEE-TPAMI	220	Article
10	Dwivedi Y.K. et al.	Impact of COVID-19 pandemic on information management research and practice: Transforming education, work and life	2020	IJIM	186	Article

According to Table 6, four articles have been published in the journals of IJCV and IJIM (two articles for each one). While one article has been published in the IEEE-TNNLS journal. The article of Lin T.-Y., et al. in 2020 recorded the greatest number of citations (1069) until the date of search and data collection.

### 4.3. Co-Authorship Analysis

Co-authorship analysis is widely utilized to highlight the patterns of scientific collaboration through figures called “co-authorship networks” where nodes are countries, organizations, or authors. Connections among nodes refer to the shared authorship of a certain paper (Figure 2).



**Figure 2.** Co-authorship of authors in the leading AI journals during 2020 and 2021.

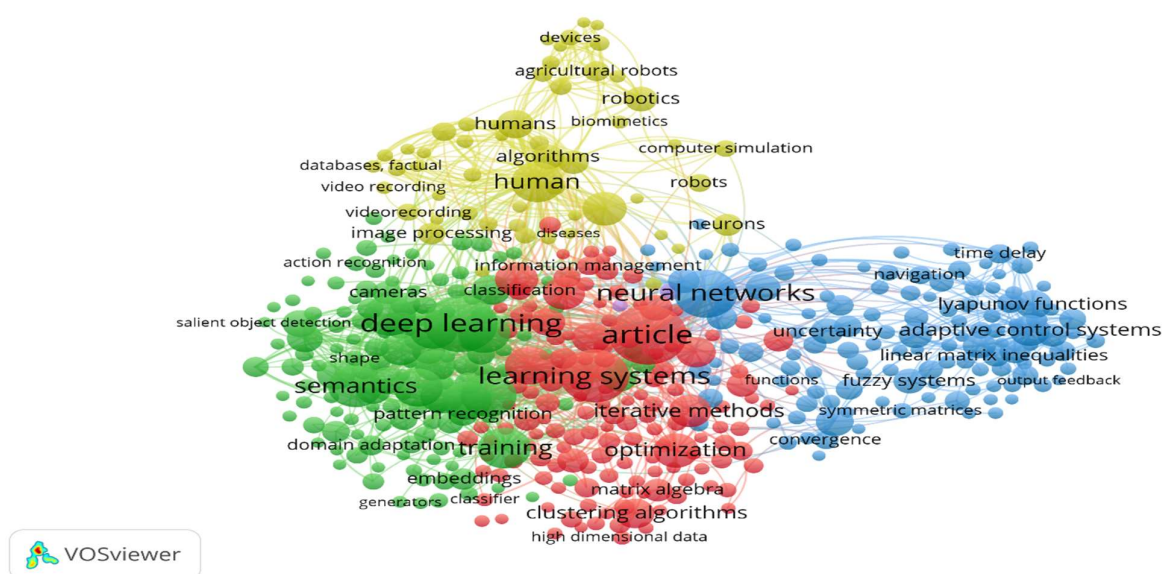
Using the VOSviewer network visualization and analysis platforms, Figure 2 shows the co-authorship network of authors, publishing a minimum of 30 co-authored documents with at least 300 citations in 2020 and 2021 (total of 62). The color of the nodes represents the clusters (modularity class) of the AI leading journal authors. Within the network, the

size of the nodes represents the extent to which an author is prominent, and the strength of arrows represents co-authorships. A total of seven clusters were identified. Chen J. and Chen X. affiliated with Beijing Institute of Technology and Shenzhen Guangdong, China, respectively, represent the strongest co-authorship cluster, with other thirteen co-authors in multiple publications in the leading AI journals. They are followed by Chen, H. National Tsing Hua University, Hsinchu, Taiwan and Li, Y., Li, Y., Tsinghua University, Beijing, China who contributed with eight more co-authors in a publication in the AI leading outlets. For instance, topics explored by Chen X. and team looked at the extent to which differentiable architecture search (DARTS) would enable effective neural architecture search (NAS) by adopting the novel approach of Partially-Connected DARTS (PC-DARTS). While adopting the gradient descent, they reported that previous trials of using the DARTs would lead to negative sides such as computational costs and high memory [39]. Another example from the second cluster [40] includes a number of articles that explored topics such as proposing a systematic solution for RGB-D salient object detection in which they highlighted the benefits of the proposed multi-modal fusion pattern in fusing and selecting cross-modal complements [40]. In addition, themes such as social interactions and their relationship with personal and professional life through adopting the deep Classification-Regression Network (CR-Net) to further analyze the Big Five personality challenges were explored [41].

#### 4.4. Co-Word Analysis

Co-word or co-occurrence analysis employs text-mining methods to the articles' keywords, abstracts, and titles [34]. It is conducted to highlight the authors' keywords which mostly reflect the articles' content [42]. The co-occurrence of keywords occurs in articles when a couple of keywords are repeated together, which consequently reflects the extent to which the two concepts are related [34]. Co-occurrence is mostly used to extend knowledge, outline innovation, and assess performance, within the management and strategy contexts [43,44].

Figure 3 presents the co-occurrence analysis of the most frequent themes discussed at least 30 times in the leading AI journal publications during the COVID-19 pandemic (2020–2021). Word combinations such as “task analysis–training”, “deep learning–convolutional neural networks”, “learning systems–optimization”, “neural networks–adaptive control system”, “human–algorithm”, and “artificial intelligence–machine learning” exhibit stronger links with more frequent co-occurrence in the leading AI journal publications (2020–2021).



**Figure 3.** Co-occurrence of author-specified keywords appearing at least 30 times in the leading AI journals publications during 2020 and 2021.

Such co-occurrence of author-specified keywords reflects various AI themes. For example, task analysis and training-related themes are discussed through the understanding of the adaptive ConvNet via mutual learning from different model configurations [45]. Authors proposed a novel method (i.e., MutualNet) to train a single network that can run at a diverse set of resource constraints and can possess various input resolutions and network widths. Furthermore, scholars who studied artificial intelligence along with machine learning looked at general novel frameworks for automatic distributed active learning (AutoDAL) during the COVID-19 pandemic [46]. They aimed to address the various problems and challenges in active learning (i.e., imbalanced datasets and limited labeled data) to enhance the optimization efficiency and handling of big data. Other keywords such as deep learning–convolutional neural networks were utilized in studies that investigated the emerging research of dynamic neural networks, which has been recently attracting deep learning scholars' attention [47]. A study by Han et al. looked at the extent to which a dynamic network can adapt its parameters to various inputs to achieve accuracy, adaptiveness, and computational efficiency. In addition, they examined the decision-making schemes, applications, and optimization techniques that can be used to resolve AI-challenging problems and hence, enhance future research directions.

## 5. Discussion of Findings

The COVID-19 pandemic has been imposing new challenges that can be tackled by employing a range of digital technologies, particularly AI [48]. The bibliometric analysis in the current study is used to uniquely conclude the process of current and previous research citation analyses so academics can learn about the directions for future research [49]. Specifically, the study is considered an attempt to strengthen the research field of "AI" by using bibliometric analysis. The key trends and themes of AI research during the time of the COVID-19 pandemic (2020/2021) are reported. Leading AI scientific journals in the Scopus database were scanned for AI articles (a total of 5890 documents) to provide insights into the current knowledge on AI and report on the key authors and publications to show how the topic has been evolving during the pandemic. The results extend previous literature, promote transparency, and offer an opportunity for future academics who are willing to advance the current body of knowledge on AI and also guide them on the leading AI journals and key themes.

The descriptive analysis or productivity analysis (i.e., annual production, most productive authors, countries, and organizations) and the network analysis (i.e., citation analysis, besides, social structure (co-authorship analysis) and conceptual structure (i.e., co-occurrence/key-words analysis)) of the leading AI journals are all presented. Descriptive analysis shows that *IEEE-TNNLS* and *IEEE-TPAMI* are the top AI journals publishing the highest numbers of articles, particularly in 2021; a year after the start of the pandemic.

The current study results are shown that the journal *IEEE-TNNLS* and the journal *IEEE-TPAMI* have published the highest number of articles. While the journal *IEEE-TPAMI* is the second regarding the number of published articles, it is the outlet for the top three most cited articles within the AI leading journals. Nevertheless, the journal *IJCV* and the journal *IJIM* can be considered potential outlets for AI future studies. For academics to influence the AI research community, it is suggested to target the leading AI journals as the top publication outlets for their future studies.

Interestingly, the descriptive analysis is showing that none of the topmost productive authors has authored or co-authored any of the top 10 most cited articles within the AI leading academic journals, both lists include different information which reflects that citation is geared more towards certain trendy topics in AI and the number of published articles for each author in this research field does not guarantee a high number of citations. However, the authors in Tables 3 and 6 are seen to be strongly added and shaped the AI research field by offering valuable contributions to the theoretical and practical implications during the COVID-19 pandemic. It is also noted that China is the most productive country in the leading AI journals during (2020 and 2021) and the home of the top ten productive authors,

however, the Chinese leading and most productive institutions come after the top of the list which happens to be a UAE institution (i.e., Inception Institute of Artificial Intelligence, Abu Dhabi) with 25 published documents. School of Artificial Intelligence, University of Chinese Academy of Sciences is the top institution in China with 20 published articles followed by the University of Chinese Academy of Sciences with 19 published articles.

In addition, unique findings were heightened through the use of bibliometric/network analysis. For example, the results of citation analysis are showing that the top-cited articles were first, “Focal Loss for Dense Object Detection” authored by Lin T.-Y., et al. (2020) which received 1069 citations. Secondly, “Squeeze-and-Excitation Networks” (Hu J., et al., 2020) with 776 citations, and thirdly “Mask R-CNN” (He K., et al., 2020) with 659 citations. The focus of the top-cited articles is on topics related to convolutional neural networks (CNNs), object detection in images, instance-level recognition, and instance segmentation. Moreover, the article focusing on “Squeeze-and-Excitation Networks” by Hu J., et al. (2020) [50] is also at the top of the most-cited articles which is employing repeated terms to the top-cited article (i.e., convolutional neural networks (CNNs)). However, it is expected that the number of citations for “deep learning” and “artificial intelligence” articles will continue to increase in the future.

The co-authorship analyses also revealed remarkable results related to the AI articles’ seven co-authorship clusters. Chen J. and Chen X. affiliated with the Beijing Institute of Technology and Shenzhen Guangdong, China was included in the first and strongest cluster respectively, along with other thirteen co-authors in multiple publications in the leading AI journals. They are followed by Chen, H. National Tsing Hua University, Hsinchu, Taiwan and Li, Y., Li, Y., Tsinghua University, Beijing, China who contributed with eight more co-authors in a publication in the AI leading outlets. This refers to the strong existence of Chinese scholars within the top AI journals published in 2020–2021.

Interestingly, some of the keywords of the most cited topic happened to be the keywords mostly used in the AI leading journals 2020–2021. For example, the frequent occurrence of the term “task analysis–training”, and “deep learning–convolutional neural networks,” in the papers, refers to their high domination within AI research. In addition, the “optimization” and “artificial intelligence” topics have become more important during the COVID-19 pandemic. Another notable result is related to the occurrence of the term “learning systems” and the frequent citations of “Focal Loss for Dense Object Detection” [51] which is considered a relatively new area of research focusing on terms such as “learning systems”, “neural networks” and “convolutional neural networks (CNNs)”. Such terms in turn showed a high co-occurrence within the study scope of the AI leading journals.

Moreover, other certain topics in the leading AI journals during the COVID-19 pandemic were also identified. Articles focused on “deep networks and visual explanations” [52] have been frequently cited followed by articles on “deep Learning for generic object detection” [53]. Therefore, the two topics are considered more influential within the AI leading journals. In contrast, articles on “Artificial Intelligence (AI) challenges and opportunities” [54], “Multi-Scale Backbone Architecture” [55], and “Impact of COVID-19 pandemic on information management research and practice” [56] have received a lower number of citations, perhaps due to they are just recently published. However, it is believed that the trendy topic of “responsible AI development” [57,58]. and “augmented processes” [59] could be receiving a high number of citations due to its recent popularity. Interestingly, articles related to “information management and” “learning systems” [18] seem to be more neutral rather than specific.

## 6. Implications

The present review article holds several beneficial theoretical and practical implications. Concerning the theoretical contribution, this paper adds to the existing body of knowledge associated with AI within different contexts and settings by highlighting and outlining the essential trends and thematic evolution of AI research produced by the leading AI journals over the two recent years. In addition, the current study provides an

in-depth understanding of the conceptual structure as well as the social structure of the publications of the highest rank journals belonging to the subject area of AI amidst the COVID-19 era, particularly in the years 2020 and 2021. The results of the current work revealed that there is a substantial number of publications on AI (e.g., articles, review studies, editorials, conference papers, etc.) during the last two years among the selected journals. Having said that, this could reflect the considerable attention that has been paid by scholars and researchers from many countries all over the world to this area of research. This could also lead to increased attention by authors around the world to AI and its linked issues among various sectors in the future. Moreover, the findings of this paper represent informative details and outstanding contributions to concerned stakeholders (e.g., authors, research-related centers, higher education institutions, and others) by conducting a comprehensive bibliometric approach consisting of a multi-method technique (i.e., productivity analysis, citation analysis, co-authorship analysis, keywords analysis, etc.) to deeply analyze and map the scientific production of the leading AI academic journals indexed in Scopus database. Our research findings provide obvious overviews of the most prolific scholars, countries, and institutions that contributed to the top 10 journals in the AI area. Another theoretical contribution of this research is connected to research methods. In other words, employing an integrated bibliometric analysis involving evaluative measures (i.e., annual production, most productive authors, nations and organizations, and most cited documents) and relational techniques (i.e., co-authorship analysis, keywords or co-occurrence analysis) adds to the extant literature on bibliometric studies within different areas and domains. In this vein, this paper, to the best of the authors' knowledge, is considered the first attempt to employ a comprehensive bibliometric analysis of the leading AI academic journals indexed in the Scopus database, one of the biggest abstract and citation databases of peer-reviewed literature.

Regarding the practical implications, the current scientific research produces a variety of contributions for policymakers, managers, and relevant stakeholders in connection with the AI area. To be more specific, the results of the current paper do assist policymakers and managers of different relevant organizations in formulating and developing timely strategies and procedures related to AI and its applications among various industries and sectors. In other words, it is evident that AI-associated studies are industry-based and could offer policymakers and managers of industry and related sectors benefits in terms of forming and deploying efficient strategies of AI and bringing proper solutions for its opportunities and challenges.

## 7. Limitations

Like any academic work, this study has potential limitations that have to be highlighted and considered in future research. The first limitation is related to the target journals. As previously discussed, this research did target only the top 10 academic journals of AI, depending on the most recent CiteScore metric produced by Scopus Elsevier. The second limitation is linked to research methods. As mentioned, this study used some bibliometric techniques involving evaluative metrics (e.g., productivity and citation analysis) and relational methods (e.g., co-authorship analysis and co-occurrence/keywords analysis). The third limitation is related to the given period (2020 and 2021) that was considered while gathering the data from the targeted AI journals. At last, the study analysis suggests the development of four key shifts in the leading AI journals during the COVID-19 pandemic. Such shifts are geared toward themes such as "deep learning" and "optimization", "artificial intelligence", and "clustering algorithm", which revealed the multifaceted nature of AI topics.

## 8. Conclusions and Future Scope of Work

To conclude, this paper has highlighted the major trends, conceptual and social structures, and key themes of AI leading journals' publications during the period 2020–2021. It has also generated several promising research directions that are important but under-



explored in current research. First, future work is suggested to review, analyze, and map the scientific production of the rest of the journals belonging to the subject area of AI such as first-quartile AI journals; second-quartile AI journals; third-quartile AI journals; and/or fourth-quartile AI journals. This could assist in producing a deeper and noteworthy understanding and overviews concerning the big data of AI journals. In addition, review studies of AI big data are recommended for future work to provide an in-depth systematic review of publications in AI-associated academic journals. In addition, future research could conduct a bibliometric analysis of the research methods, data analysis techniques, and procedures of the publications of the leading AI journals. Next, future research could go beyond the two-year period (2021–2022) and collect data from top-tier AI journals for several years (e.g., one decade, two decades, etc.). This will help in bringing a full illustration and solid background on the scientific production of these journals over the last years. Fourth, recent publications may show top AI authors who may have changed their affiliations after moving to a new position, this may influence the order of the most productive organizations in the leading AI journals. Moreover, future research could be focusing on identifying a more generalizable theoretical framework that may capture the complexity of “learning systems” and advance the academic understanding of “clustering algorithm” in the context of “visual attention modeling” so experimental results could potentially enhance performance in time cost and accuracy. It is suggested that “Computation theory” could be advanced concerning its three main branches; namely computability theory, automata theory and formal languages, and computational complexity theory, to provide more insights into the limitations and fundamental capabilities of computers. “Graph” theory could also present a potential theoretical framework that covers concepts that can develop the mathematical structures used for modeling objects’ pairwise relations, which is a crucial principle of discrete mathematics studies. Indeed, the AI domain is too broad and includes various disciplines. Thus, future research could focus on specific domains such as CV, NLP, etc. This could help in presenting more precise and solid findings.

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