Exploring the Research Trends in COVID-19 in Collaboration with Industry 4.0 Technology as an Indispensable Effective Tool to promote Global Health through Bibliometric Analysis

Neha Divekar*, Nilishaltankar and Shilpa Malge  
Symbiosis Institute of Technology, Symbiosis International (Deemed University), Lavale, Pune, Maharashtra, India  
Email: neha.divekar@sitpune.edu.in*

Abstract. Objective: Currently, the entire world is dealing with a lethal crisis caused by COVID-19. SARS-CoV-2 is the root cause of the new disease Coronavirus. Novel Coronavirus has gripped more than 215 countries and territories worldwide. This study provides the bibliographic analysis of data on the epidemiological research conducted on COVID-19 and technology-based tools and applications extensively used to study and interpret the Coronavirus to tackle the pandemic in every way possible. Method: We investigated the data from the Scopus search engine, Google Scholar, and World Health Organization (WHO) using associated terms like Coronavirus, COVID-19, Artificial Intelligence (A.I.), Machine Learning (ML), Big data, Internet of Things (IoT). The data stretches from December 2019 up to 9 May 2020. Result: A.I., an ML-supported platform, is used by many agencies worldwide. Out of 217 publications from 57 countries, China and United States contributed maximum technology-based research articles in correlation with COVID 19. Conclusion: The world is in the middle of a pandemic due to COVID-19. Globally human health has been impacted. This paper attempts to understand the intellectual pattern of COVID-19 and 4.0 industry tools in research using the Scopus database and conducting the bibliometric analysis. This bibliometric analysis would also facilitate future researchers' pathway to identify research carried out in COVID-19, focusing on A.I., ML, and advanced digital technologies. It would develop the existing knowledge potential and help future researchers collaborate and facilitate interdisciplinary research to tackle the pandemic better. 

Keywords: COVID-19, novel coronavirus, coronavirus disease, bibliometric, Artificial Intelligence (A.I.), Machine Learning (ML), Big data, Internet of Things (IoT).

1. Introduction

Novel Coronavirus (COVID-19) is the new normal. The virus knows no boundary and received pandemic status within a month of its first reported case. Since its origin in Dec 2019 in Wuhan city of Hubei province of People's Republic of China, it has spread worldwide. It has led to a war-like condition in the world. This lethal virus has massively impacted people's daily lives, business, physical & mental health in most of the cities of many countries, as observed under lockdown. In addition to that, even the global economy seems hampered. The world is battling against protecting its economy from crumbling and dealing with reviving the economy head-on[1].

World Health Organization (WHO) declared the outbreak a public health emergency of international concern on 30 January 2020. After Diagnosis and isolation of the virus, Severe Acute Respiratory Syndrome Coronavirus (SARS CoV 2) was named COVID-19 on 11 February 2020[2].
As per WHO report, as of 28 July 2020 worldwide, 215 areas or territories are affected, infecting 16,341,920 people around the world with 650,805 confirmed deaths and new cases everyday, proving it to be highly contagious; however, the mortality rate is 2.5 to 3% approximately [3]. USA, Spain, Italy, U.K., Russia registered the highest cases (WHO, 2020).

COVID-19 attacks the host cell through the ACE2 receptor and is also known to damage the myocardium and cardiovascular system [4]. Reports of NIH say the early symptom of disease appears in 2 to 14 days on exposure to the virus. It includes cough, trouble in breathing, fever, chills, muscular pain, sore throat, and the new one added to the list is the loss of taste or smell. The symptoms vary depending on the patient's age, immunity, and underlying medical condition [5]. The virus transmits (Person-to-person) from one human body to several others resulting in community transmission. This happens through direct contact or by saliva droplets spread during coughing or sneezing from an infected person [6].

Latest technology like Artificial Intelligence (A.I.), Machine Learning (ML), Big data, Internet of Things (IoT) played a major role in helping Health workers, Government (worldwide) to take correct steps to control the rate of spread. AI-based software can reduce the time required to identify a person’s status of being corona positive or negative [7]. A.I. supports in recognition of the infected cases with the aid of Medical imaging technology like computed tomography (C.T.), magnetic resonance imaging (MRI) scans of different parts of the human body [8]. This paper aims to correlate the industry 4.0 technology and trends of COVID-19 research globally since the time of its outbreak in December 2019 [9].

Digital technologies are working hand in hand with medical professionals to combat the current epidemiological crises. In these trying circumstances IoT, A.I., ML are playing a crucial role in regulating the economy and social operations [10]. Drones are multi-tasking and serve as a very useful tool; it ensures surveillance to keep a check on social distancing norms as set by the government bodies of various nations and can also be used to spray disinfectants on virus prone zones. Not only that but with the advent of digital tools, there is no need for labor-intensive temperature inspection and distance scrutiny [11].

Technological tools along with the data can help in prediction and analysis concerning the current pandemic. Digital technology can be impactful only if effective regulation by the Government is accompanied by it. Technology comes up with its pros and cons. Although it promotes human well-being, security and privacy problems creep up. Sometimes, wrong information or inadequate information reaches the masses [12]. Info emic has to manage well and in time, which is possible only with the correct technology usage. The company studies the customer data to work towards sustainable development [13]. The importance of advanced technologies to manage the current crises cannot be discarded, and there is a grave requirement of their enactment in tracking COVID-19 statistics. Big data and advanced analytics have come to the rescue of researchers, policymakers, health professionals, and epidemiologists to understand the pathway and effect of the COVID-19 pandemic [14]. Thereby accentuating tracking and promoting predictions in time; so that proactive measures and decisions can be taken by the concerned authorities to reduce the coronavirus curve [15]. With the help of GPS data, community movement can be navigated and understood by the government officials; to comprehend whether rules and regulations are being followed strictly or violated by the people [16].

Technologies such as blockchain telemedicine, A.I., IoT, and ecological revolutions are trying to make work, life, and education functional as everything can be done virtually with minimum physical contact. Digital chatbots and webbots are becoming useful communication and health care aspects [17].

The virus has affected human life at all levels, so diversity in research is important. The bibliometric analysis has made it clear that extensive research was carried out in such a short span. The findings identify the most productive authors in that period and the merging research areas. This paper attempts to understand the intellectual pattern of COVID-19 and 4.0 industry tools research conducted on them, using Scopus database and conducting bibliometric analysis [18].
With the help of a mobile-based survey, susceptible virus carriers can be identified with the advent of machine learning algorithms. This design would also help get information on the supposed virus carriers and the places visited by them by using Google location history [19]. Digital technologies facilitate timely detection and effective management of infectious diseases. Industry 4.0 tools play a significant role at all stages of the Coronavirus crisis like tracing, checking, Diagnosis, monitoring, and observation, which would help healthcare workers avoid physical contact with the patients and the suspected carriers.

COVID-19 can be handled well by embracing the fourth industrial revolution named Industry 4.0. Industry 4.0 is catering to manufacturing and supplying healthcare equipment and is playing a crucial role in developing the vaccine and medications, which are still in the development stage but, once developed, would save human lives. Advanced digital tools and technologies are necessary to bring the disease under control by aiding in correct Diagnosis based on the correct analysis of the symptoms, manufacturing customized face masks, and proper information dissemination. Surveillance systems can even provide day-wise updates of the positive detected patients and information related to their area and age-related details. Not only the medical fraternity but also the current online blended learning in the educational sector.

A.I. and radiological imaging tie-up would accelerate the speedy detection process of COVID-19 and help rural villages where there is a shortage of specialized medical doctors. There is a rising need for telemedicine and e-healthcare to maintain social distancing during the Covid crisis, thereby enabling support to quarantine people. This can be implemented only by employing tech-based tools. 4.0 tools will also cater to the ever-rising psychological healthcare under the current circumstances. COVID-19 has deep-reaching traumatic effects on patients' mental health, their families, and even the medical fraternity. IoT-based tools and services must be advanced to facilitate better digital psychiatric services along with A.I. This also calls for collaborative research between psychiatrists and engineers to help in stress diagnosis and alleviate mental health disorders. This paper will help future researchers to collaborate and facilitate inter-disciplinary research.

Machine learning algorithms help comprehend the spread pattern in less time with more Accuracy and enhance the Diagnosis. ML has been used to classify coronavirus genomes, suspected cases so that protecting stratagems could be advanced. Accelerating the use of data mining techniques and developing novel text is indeed a pressing need in front of the A.I. researchers.

New compounds similar to drugs against SARS-CoV-2 have been designed with deep learning. Google has developed a deep learning system named AlphaFold. Protein structures associated with Coronavirus are developed faster-using technology than using the traditional way, thereby providing the pathway to developing formula for vaccination. The development of the vaccination and A.I. and ML also help ineffective hospital management and operation.

A.I. can also help us find out where the next massive spread may take place. A Canadian company named Blue Dot was the first to convey information extracted using A.I. based application about the outbreak in Wuhan in December 2019. Imperial College London came up with a Benevolent A.I. application and stated that baricitinib would act as a useful medicine for Coronavirus. A.I. applications focus on Accuracy, which gets better with each scan. A company based in Hong Kong developed six new molecules using A.I., which could curb viral duplication. A.I. algorithm can help study images of the lung to detect the virus and distinguish it from other respiratory diseases, as is being used by an organization named 'Infer vision' based in Beijing. Medical professionals' burden must be lessened, and it has become a reality with adequate help from advanced technologies. A Lung CT scan can help get information about the shape, density, and volume of the virus, leading to correct judgment in 10 seconds.

This bibliometric study would provide novel prospects for future researches so that apt synthesis can be carried out for further work in this domain. This paper has been written to discover research tendencies regarding the amalgamation of advanced digital technologies concerning the COVID-19 crises. This analysis would also facilitate collaborative interdisciplinary research.
2. Data Collection
The data for this paper were retrieved from the Scopus database on 9 May 2020. The term Scopus is derived from the word "Hammerkop" (Scopus umbretta), a bird’s name. Three hundred researchers and 21 research organizations, along with librarians, have contributed to developing this abstract and indexing database by the Elsevier Co. Scopus are duly recognized for brilliant steering skills. It includes American, European, and Asia Pacific Journals in myriad languages. Scopus database encompasses 27 million abstracts with citations dating back to 1966.

Initially, the main keyword was given to extract primary data from the database. Preliminary research indicated that only six papers were published in the year 2019, whereas a steep raise of 6351 publications were seen in the year 2020 compared to the preceding year. The total papers published on "COVID-19" from 2019 to 9 May 2020 were 6357 in Scopus; before that, there were no publications regarding the given main keyword to the database.

2.1 Country-wise Publication Data Highlights
The percentage of papers published country-wise in the period mentioned above is provided in Figure 1, which highlights China’s highest contribution, followed by the U.S. concerning the main keyword COVID-19.

![Figure 1: Country-wise Publications](image)

2.2 Subject-wise Publications Search Results
Primary research statistics indicate that in the period between (December 2019 to 9 May 2020) the maximum numbers of papers were published in Medicine, followed by Biochemistry, Genetics, and Molecular Biology. Immunology and Microbiology stand third in terms of subject-wise publications attributing to the keyword- "COVID-19". Figure 2 shows the Subject-wise Publications.

2.3 Funding Agency-wise Publications Statistics
One hundred ninety-one papers could be published with funding from the Natural National Science Foundation of China. At the same time, 61 papers were published with grants received from the National Institutes of Health, followed by 33 papers funded by China’s National Basic Research Program. Thus, the country where this pandemic originated contributed maximum funds to carry research in COVID-19. After executing a primary search, the data was further mined with aid from some Secondary keywords, as mentioned in section 1.4. These funding agencies’ references would be beneficial for future researchers.
2.4 Significant Secondary Keywords
The keywords were divided into two groups—namely Main-keyword and secondary keywords. Table 1 shows the Extracting Data from keywords. To conduct this research on the correlation between A.I. and allied technology on COVID-19, the following keywords were used as a key to unlock data from the Scopus database.

Table 1: Extracting Data from keywords

| Main-Keyword (AND) | COVID-19 |
|-------------------|----------|
| "Artificial Intelligence" OR "Machine Learning" | "Artificial Intelligence" OR "Machine Learning" |
| OR "IOT" OR "Big data" OR "Robotics" OR "Statistical Analysis." | OR "IOT" OR "Big data" OR "Robotics" OR "Statistical Analysis." |

2.5 Data Investigation
To understand the individuality of research carried out on COVID-19 and A.I., ML, IoT, Big data, Robotics, and Statistical Analysis, Bibliometric analysis of the collected data was carried out. A literature survey was conducted to understand the mechanism of this deadly virus, intricacies related to COVID-19, and the technological angle associated with it. Distinguished researches on COVID-19 provided the data for writing this paper. The analysis was carried out concerning distinguished researchers, affiliation, subject areas, funding agencies, source titles, document type, and country-wise information related to published papers. Lastly, a conclusion was drawn based on the analysis for further application and support to humanity under the current difficult and challenging situations in front of the world due to the COVID-19 pandemic.

3. Bibliometric Analysis
Bibliometric analysis of the data collected was performed for the following:

3.1 Geographical Regional Analysis
The world map is drawn using a google spreadsheet, and it showcases the country-wise locations where papers on the topic mentioned above are published. The world map given below shows the places' geographical locations, which made their research contributions via publications. From the map in Figure 3, it is evident that maximum papers have been published in the countries which were hit hard with pandemics, and a lesser number of papers have been published where the impact of the virus was not that predominant.
3.2 Country-wise Search

Figure 4 provides statistical details related to country-wise publications. China occupied the top-most position in publishing. The United States seconded in line and trailed by the U.K. Overall, 57 countries have published papers and contributed to the Scopus database’s research share. Thus, it can be inferred that maximum publications are from the country where this COVID-19 affected most. Seventeen countries have just one publication to their credit, indicating a dearth of research in those regions. To name a few research contributors after the first three categories are Italy, Taiwan, Germany, France, Japan, Hong Kong, and the Netherlands; who are trying to keep pace with the first three are as follows:

3.3 Affiliation Statistics

Table 2 displays the six-best affiliations from 2019 till 9 May 2020 from the main and secondary keywords provided to the Scopus database. The bibliometric analysis indicates that the Chinese Academy of Sciences has made a maximum contribution by publishing eight papers. In contrast, the University of Chinese Academy of Sciences stands at position six with six publications. Grippingly, major universities/organizational affiliations were from China and Hong Kong.
| AFFILIATION                               | No of Papers | Percentage |
|------------------------------------------|--------------|------------|
| Chinese Academy of Sciences              | 8            | 29%        |
| Ministry of Education China              | 7            | 25%        |
| Chinese University of Hong Kong          | 7            | 25%        |
| Imperial College London                  | 7            | 25%        |
| The University of Hong Kong              | 6            | 22%        |
| Kaohsiung Medical University             | 6            | 22%        |
| University of Chinese Academy of Sciences| 6            | 22%        |

### 3.4 Subject Areas
Figure 5 shows the subject areas in which publications have been made since 2019 till 9 May 2020. Figure 5 clearly indicates that maximum research was carried out in Medicine, amounting to 155 papers. After which a drastic drop is visible as the number falls down to 25. The least number of publications were in Dentistry, Material Sciences, Nursing and Arts and Humanities.

![Figure 5: Subject-wise Publications](image)

### 3.5 Author Statistics
The statistics provided in Table 3 indicate a list of authors who made the maximum contribution to the research field by publishing a greater number of papers. This analysis helped in comprehending the stimulus of an author.

| AUTHOR NAME   | No of Papers | Percentage |
|---------------|--------------|------------|
| Hsueh, P.R.   | 4            | 10         |
| Briganti, A.  | 3            | 7.5        |
| Chen, T.C.    | 3            | 7.5        |
| Chen, Y.H.    | 3            | 7.5        |
| Gao, D.       | 3            | 7.5        |
| Haleem, A.    | 3            | 7.5        |
| He, D.        | 3            | 7.5        |
| Javaid, M.    | 3            | 7.5        |
| Lou, Y.       | 3            | 7.5        |
| Roupré, M.    | 3            | 7.5        |
| Vaishya, R.   | 3            | 7.5        |
| Wang, W.      | 3            | 7.5        |
| Yang, C.J.    | 3            | 7.5        |

### 3.6 Journal Statistics
The Journal statistics revealed that the quarried data was published in the form of Articles, Review papers, Editorial, Notes, Letters, Short surveys, Data papers, and Conference papers. The extracted information reveals that 58.99% of articles were published from 2019 till 9 May 2020, followed by review articles and Editorials. Figure 6 validates the percentage of the type of publications based on the short-listed keywords. It is also observed that only one Conference paper was published since 2019, whereas the percentage of short survey and data papers was quite low.

![Figure 6: Journal Statistics](image)

### 3.7 Source Statistics
Statistical analysis of the source titles and number of publications indicated that the International Journal of Environmental Research and Public Health made the highest contribution in terms of publishing ten papers. At the same time, six papers were published by MBJ and the Journal of Microbiology-Immunology and Infection. It is significant to record that 143 Journals published research papers on the given main and secondary keywords.

![Figure 7: Source Title and Number of Publications](image)

### 3.8 Citation Analysis
A powerful and user-friendly interactive network visualization and analysis tool named Node XL was used to create Figure 7 shows the Source Title and Number of Publications. Leveraging of M.S. Excel application becomes easy for representing graphical data and carrying out advanced network analysis. This social network analysis software was used to execute network analysis of the number of citations received per publication from 2019 till 9 May 2020. Importing nodes and edges into an excel spreadsheet is facilitated to support multiple data network providers, which is embedded in this
effective research tool. The graphical data can be operated easily because of the excel template accompanying this software. Figure 8 portrays 99 vertices and 76 edges. This tool helps in carrying out bibliometric research analysis on varied topics. Figure 9 illustrates 638 vertices and total/unique edges 738.

![Figure 8: Citation Analysis](image1)

![Figure 9: Visual Network of Authors and Keywords](image2)

3.9 Language-Specific Publication

After a bibliometric study of the data collected from the Scopus database; it is clearly visible that out of the total number of 217 publications; maximum publications are in the English language, followed by ten papers in Chinese. Interestingly, it was discovered that there were two publications in French-English, two in Spanish-English, one in French, and one in German. Bilingual publications make research understandable to diversified readers and increase readership. Figure 10 shows the visual representation of language-specific publications.

![Figure 10: Language-Specific Publications](image3)

4. Limitations of the Present Study

To the best of our knowledge, this is among the first bibliometric analysis to interpret the global COVID-19 research yield in relation to industry 4.0 technology. Nevertheless, there are some limitations in our work. SCOPUS and the WHO databases are explored in our survey, but they're still some publications that were not in our scope. Many other databases can be used in the future, like EBSCO, PUBMED, etc., to collect wide-ranging data with respect to Corona virus and advanced technologies. Our dependency on indexed databases, as happened in a most bibliometric study cannot
be denied. This article has been written to facilitate future researchers to identify researches carried out in COVID-19 with a focus on A.I., ML, and advanced digital technologies. By studying specific papers, researchers would get an overall view of what kind of research has been funded by the funding agencies, reading papers by the most prolific authors in this period. So that additional gaps can be located and new practical solutions to existing problem areas can be explored and implemented in the future. The graph of how different countries have handled and contributed to the pool of Epistemological knowledge about the collaboration between Corona virus and industry 4.0 tools can be studied, and collaborative research can be carried out with the researchers from the countries where maximum publications were made in this selected period.

5. Conclusion
Human health internationally is under threat due to the outbreak of COVID-19. Healthcare services globally are fighting together to serve humanity and demands relevant research and technological interventions in this sector that can help outline the clinical and pathogenic characteristics of this disease.

Technology is a game-changer in the 21st century in all walks of life. There is a need to make timely and good use of A.I., ML, IoT, and Data Mining to solve the pressing problem standing at the face of humanity today. This paper provides the status of how much work has been done in this area country-wise and will present the current picture of the medical system's capabilities in dealing with this pandemic using technology. So, that future work can be targeted towards the areas unexplored or less explored.

The keywords have helped in generating a holistic all-inclusive view pertaining to the papers published, ranging from business, urology, cancer management, COVID-19 treatment, precautionary measures, economy, dentistry, education, psychiatry, etc. Future work can be continued based on the work already done by these researchers. The work of the most productive researchers can be studied, and future research can be built on it. Their work may help create empirical research opportunities and new models; theories can be designed after examining the existing ones. It will also pave the pathway towards a beneficial future for humanity and health care organizations. Lastly, it would help future researchers to collaborate and facilitate inter-disciplinary research to tackle the pandemic in a better way.

Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of interest
None.

References
[1]. Cascella, M., Rajnik, M., Cuomo, A., Dulebohn, S. C., & Di Napoli, R. (2020). Features, evaluation, and treatment Coronavirus (COVID-19). In Statpearls [internet]. StatPearls Publishing.
[2]. Chahrour, M., Assi, S., Bejjani, M., Nasrallah, A. A., Salhab, H., Fares, M., & Khachfe, H. H. (2020). A bibliometric analysis of Covid-19 research activity: A call for increased output. Cureus, 12(3).
[3]. Dong, E., Du, H., & Gardner, L. (2020). An interactive web-based dashboard to track COVID-19 in real-time. The Lancet infectious diseases.
[4]. Gozes, O., Frid-Adar, M., Greenspan, H., Browning, P. D., Zhang, H., Ji, W., ... & Siegel, E. (2020). Rapid ai development cycle for the Coronavirus (covid-19) pandemic: Initial results for automated detection & patient monitoring using deep learning ct image analysis. arXiv preprint arXiv:2003.05037.
[5]. Gorbalenya, A. E., Baker, S. C., Baric, R. S., Rijnd Groot, D. C., Gulyaeva, A. A., Haagmans, B. L., ... & Neuman, B. W. (2020). Severe acute respiratory syndrome-related Coronavirus—The species and its viruses, a statement of the Coronavirus Study Group.

[6]. Lee, Y., Min, P., Lee, S., & Kim, S. W. (2020). Prevalence and Duration of Acute Loss of Smell or Taste in COVID-19 Patients. Journal of Korean medical science, 35(18).

[7]. Leite, H., Hodgkinson, I. R., & Gruber, T. (2020). New development: ‘Healing at a distance’—telemedicine and COVID-19. Public Money & Management, 1-3.

[8]. McCall, B. (2020). COVID-19 and artificial intelligence: protecting healthcare workers and curbing the spread. The Lancet Digital Health, 2(4), e166-e167.

[9]. Mehta, P., McAuley, D. F., Brown, M., Sanchez, E., Tattersall, R. S., & Manson, J. J. (2020). COVID-19: consider cytokine storm syndromes and immunosuppression. The Lancet, 395(10229), 1033-1034.

[10]. Nguyen, T. T. (2020). Artificial intelligence in the battle against Coronavirus (COVID-19): a survey and future research directions.

[11]. Ozturk, T., Talo, M., Yildirim, E. A., Baloglu, U. B., Yildirim, O., & Acharya, U. R. (2020). Automated detection of COVID-19 cases using deep neural networks with X-ray images. Computers in Biology and Medicine, 103792.

[12]. Peng, X., Xu, X., Li, Y., Cheng, L., Zhou, X., & Ren, B. (2020). Transmission routes of 2019-nCoV and controls in dental practice. International Journal of Oral Science, 12(1), 1-6.

[13]. Rao, A. S. S., & Vazquez, J. A. (2020). Identification of COVID-19 can be quicker through an artificial intelligence framework using a mobile phone-based survey when cities and towns are under quarantine. Infection Control & Hospital Epidemiology, 1-5.

[14]. Rothan, H. A., & Byrareddy, S. N. (2020). The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. Journal of autoimmunity, 102433.

[15]. Verma, S., & Gustafsson, A. (2020). Investigating the emerging COVID-19 research trends in the field of business and management: A bibliometric analysis approach. Journal of Business Research.

[16]. Wan Y., Shang J., Graham R., Baric R.S., Li F. Receptor recognition by novel Coronavirus from Wuhan: an analysis based on decade-long structural studies of SARS. J. Virol. 2020

[17]. World Health Organization. Coronavirus disease 2019 (COVID-19) situation report–57. Geneva, Switzerland: World Health Organization; 2020. https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200317-sitrep-57-covid-19.pdf?sfvrsn=a26922f2_2

[18]. Pandey, A. and Prakash, G., 2019. Deduplication with Attribute-Based Encryption in E-Health Care Systems. International Journal of MC Square Scientific Research, 11(4), pp.16-24.

[19]. Zheng, Y., Ma, Y., Zhang, J. et al. COVID-19 and the cardiovascular system. Nat Rev Cardiol17, 259–260 (2020). https://doi.org/10.1038/s41569-020-0360-5