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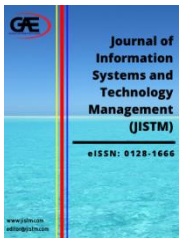

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BRIDGING PANDEMICS AND PIXELS: A COMPREHENSIVE BIBLIOMETRIC ANALYSIS OF DEEP LEARNING APPLICATIONS IN COVID-19 DETECTION

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Abstract:

The world has been significantly impacted by the global pandemic of COVID-19, leading researchers to explore various methods for detecting the virus. Deep learning (DL) technologies have emerged as pivotal tools in detecting and managing the virus. This review article aims to provide a comprehensive examination of the advancements and applications of DL in the context of COVID-19 detection, offering insights into the evolution, impact, and future direction of this rapidly evolving field. A thorough bibliometric review was carried out using the Scopus database. The methodology involved keyword-based searches, analyses of publication trends, and studies of co-citation networks, with a focus on literature from 2020 to 2023. Data visualisation tools, particularly VOSviewer, were used to analyse and map bibliometric data, highlighting publication trends, and authorship patterns. The study found a substantial rise in DL research for detecting COVID-19 from 2020 to 2023, with significant input from countries such as India, China, and Saudi Arabia. The trends in research are expected to showcase developments in DL models for medical imaging, including CT scans and X-rays, as well as the increasing significance of AI in medical diagnostics. The study also pinpointed the main collaborative networks and popular keywords in this research area. This bibliometric analysis aims to lay the foundation for future research directions by offering a comprehensive overview of the evolution of DL in COVID-19 detection It will provide strategic insights and research directions to advance this vital domain at the intersection of computational intelligence and global health.

Keywords:

Bibliometric, Deep Learning, COVID-19, Detection, Classification

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Introduction

In the wake of the COVID-19 pandemic, the scientific community has witnessed an unprecedented mobilisation of resources and intellect toward understanding and combating this global health crisis (Alokaily, 2021; Mallah et al., 2021; Oweis, 2022; Pollard et al., 2020). Central to these efforts has been the application of Deep Learning (DL) technologies, which have emerged as pivotal tools in detecting and managing COVID-19. This bibliometric analysis review article aims to provide a comprehensive examination of the advancements and applications of DL in the context of COVID-19 detection, offering insights into the evolution, impact, and future direction of this rapidly evolving field.

The onset of the pandemic posed unique challenges, particularly in diagnostic methodologies where traditional approaches struggled with the scale and urgency required. Deep Learning, with its robust capabilities in pattern recognition and predictive analytics, presented a novel solution. Leveraging vast datasets, DL algorithms have enhanced the accuracy and efficiency of COVID-19 detection, significantly impacting public health responses (Abdel-Jaber et al., 2022; Aldhyani et al., 2021; Wang et al., 2023).

This review embarks on a meticulous exploration of the corpus of literature surrounding DL in COVID-19 detection. By analysing publication trends, citation networks, and thematic evolutions, it offers a holistic view of the field's trajectory. The analysis not only highlights the critical contributions and breakthroughs but also identifies key players, collaborations, and regional contributions, painting a global picture of the research landscape. Furthermore, this review critically examines the implications of these DL applications in clinical settings, discussing their efficacy, limitations, and ethical considerations. It aims to provide a balanced perspective, acknowledging the rapid advancements while critically appraising the challenges and gaps in the current body of knowledge.

This bibliometric analysis seeks to serve as a cornerstone for academics, researchers, and policymakers, providing a detailed roadmap of the journey of Deep Learning in COVID-19 detection and offering strategic insights for future research directions in this vital domain.

Literature Review

The COVID-19 pandemic has had a significant impact on the world, and researchers have been exploring various methods to detect the virus. One promising approach is the use of machine learning (ML) and deep learning (DL) models. This literature review aims to provide a comprehensive overview of the application of ML and DL models in COVID-19 detection, focusing on the methods, challenges, and future works in this field.

Several studies have explored the use of ML and DL models for COVID-19 detection (Sedik et al., 2022; Vaid et al., 2020; Vinitha & Velantina, 2020). A comprehensive review article explored all the existing ML or DL models used for COVID-19 detection (Das et al., 2023). The review examined the applications of ML and DL in detecting COVID-19 using medical data such as CT scans. It also compared the performance of pre-trained and customised DL models for COVID-19 detection. The researchers utilised various ML, DL, and a combination of ML and DL models for extracting significant features. For this purpose, they utilised different image modalities such as CT-Scan (Serte & Demirel, 2021; Shah et al., 2021).

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Various DL models have been utilized for COVID-19 detection, including VGGNet, GoogleNet, ResNet, DenseNet, CapsNet, MobileNet, and EfficientNet (Ahmed et al., 2021; Loey et al., 2021; Oğuz & Yağanoğlu, 2022; Serte et al., 2022; Showkat & Qureshi, 2022). Additionally, the performance of major DL models such as VGG19, ResNet50, and DenseNet has been comparatively analysed over COVID-19 local CT scans and global chest X-ray datasets. While DL-based COVID-19 detection has shown promising results, there are challenges and limitations that need to be addressed. These include the need for large, diverse datasets, interpretability of DL models, and generalizability across different populations and imaging modalities.

The application of ML and DL models for COVID-19 detection shows great potential, but several challenges and limitations need to be overcome. Future research should focus on addressing these issues to further improve the accuracy and reliability of DL-based COVID-19 detection methods. Some of the promising areas of future research include the development of more interpretable DL models, the use of transfer learning to improve the performance of DL models, and the exploration of new imaging modalities for COVID-19 detection.

Methodology

Bibliometrics refers to the collection, organisation, and analysis of bibliographic data from scientific publications (Verbeek et al., 2002). Besides general descriptive statistics, such as publishing journals, publication year, and main author classification (Wu & Wu, 2017), it also encompasses sophisticated techniques like document co-citation analysis. To achieve reliable results, an effective review of literature requires an iterative sequence of appropriate keywords, a literature search, and an analysis for bibliography building (Fahimnia et al., 2015). The next section includes the adoption of search terms, the initial screening of search results, and the refinement of search results. The Scopus database is a highly valuable option for conducting bibliometric reviews due to its widespread acceptance and use by researchers for high-quality bibliometric analysis (Zyoud & Al-Jabi, 2020).

Scopus provides comprehensive coverage of academic publications, including a vast number of scientific journals and conference proceedings, which allows for significant coverage of academic publications (Rocha et al., 2022). It is widely accepted for bibliometric analyses and is used by investigators for influential scientometric analyses (Rahimi et al., 2023). Additionally, Scopus offers a rich source of data for bibliometric studies, making it a preferred choice for extracting data for bibliometric analysis (van den Noort et al., 2019). Furthermore, Scopus has been utilised for conducting bibliometric citation analysis, which demonstrates its suitability for in-depth bibliometric reviews (Novera et al., 2022). The database's extensive coverage and data-driven nature make it an influential tool for conducting bibliometric analyses, providing a robust foundation for evidence-based research (Goswami & Labib, 2022).

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Data Search Strategy

Study employed a screening sequence to determine the search terms for article retrieval. Study was initiated by querying Scopus database with TITLE (("Deep Learning" OR "Convolutional Neural Network*" OR "Deep Neural Network" OR "Artificial Neural Network" OR "neural network") AND (covid* OR sar* OR corona*) AND (detection OR classification)) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English")), thereby assembling 1848 articles. Afterwards, the query string was revised so that the search terms “Deep Learning” OR “Convolutional Neural Network” should be focussed on COVID-19 detection. This process yielded 868 results which were additionally scrutinised to include only research articles in English and articles reviews were also excluded. The final search string refinement included 817 articles which was used for bibliometric analysis. As of December 2023, all articles from Scopus database relating to deep learning and focusing on COVID-19 detection, were incorporated in the study.

Table 1: The Search String.

Scopus	TITLE (("Deep Learning" OR "Convolutional Neural Network*" OR "Deep Neural Network" OR "Artificial Neural Network" OR "neural network") AND (covid* OR sar* OR corona*) AND (detection OR classification)) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English"))

Table 2: The Selection Criterion

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2020 – 2023	< 2020
Literature type	Journal (Article), Proceeding	Book Chapter, Review

Data Analysis

The data sets, which included the study publication year, publication title, author name, journal, citation, and keyword in PlainText format, were collected from the Scopus database, spanning the period from 2020 to December 2023. Subsequently, the data was analysed using VOSviewer software version 1.6.19. This software was used to analyse and create maps using the VOS clustering and mapping methods. VOSViewer serves as an alternative to the Multidimensional Scaling (MDS) approach (Van Eck & Waltman, 2007) and shares the same goal of placing items in a low-dimensional space so that their relatedness and similarity are accurately reflected by the distance between them (Appio et al., 2014).

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While MDS focuses on computing similarity measures like Jaccard indexes and cosine, VOS utilizes a more appropriate technique for normalizing co-occurrence frequencies. Van Eck and Waltman in 2007 described this technique, known as the association strength (AS_{ij}) and it is calculated as:

$$AS_{ij} = \frac{C_{ij}}{\omega_i \omega_j}$$

which is the ratio between the observed number of co-occurrences of *i* and *j* and the expected number of co-occurrences of *i* and *j*, assuming statistical independence determines the proportionality (van Eck & Waltman, 2010). As a result, with the assistance of this index, VOSviewer can organise items into a map by minimizing the weighted sum of squared distances between all item pairs. The implementation of the LinLog/modularity normalization was carried out by (Appio et al., 2016), as documented in their research. In addition, the data set was analysed using visualisation techniques with VOSviewer, leading to the discovery of patterns based on mathematical relationships. This analysis included keyword co-occurrence, citation analysis, and co-citation analysis. According to (Zhao, 2017), the development of a research area during a period can be explored through keyword co-occurrence analysis, which has been successful in identifying popular topics in different fields, as found by Li et al. (2016). While citation analysis is valuable for identifying key research issues, trends, and techniques, it also helps in exploring the historical significance of a discipline's primary area of focus (Allahverdiyev & Yucesoy, 2017). Document co-citation analysis is a commonly used bibliometric method, and its outcome is influenced by network theory to uncover the underlying data structure. This method has been discussed in several studies (Appio et al., 2016; Fahimnia et al., 2015; Liu et al., 2015) which emphasize its relevance and applicability.

Result And Finding

RQ 1: What Are The Research Trends In Deep Learning For COVID-19 Detection Based On The Year Of Publication?

The figure 1 illustrates the trend in the number of documents published over a four-year period from 2020 to 2023, with data sourced from the Scopus database. There is a noticeable growth in the number of documents from 2020 to 2021, suggesting a significant increase in research output or interest in the field covered by these documents. The upward trend continues, though at a slower rate, into 2022, reaching a peak. This peak may indicate sustained research activity and could be reflective of a critical period of research development or response to an event such as the COVID-19 pandemic.

Despite this, there has been a small decline in the number of documents published in 2023. The decrease in research publication rates may be due to several factors, such as a consolidation phase in the research topic, a shift in research focus, or external factors affecting research publication rates, such as the natural resolution of a pandemic or the redirection of funding and resources to other areas. In summary, the figure presents numerical evidence of the growing research activity and scientific development taking place at the intersection of Deep Learning and COVID-19 detection.

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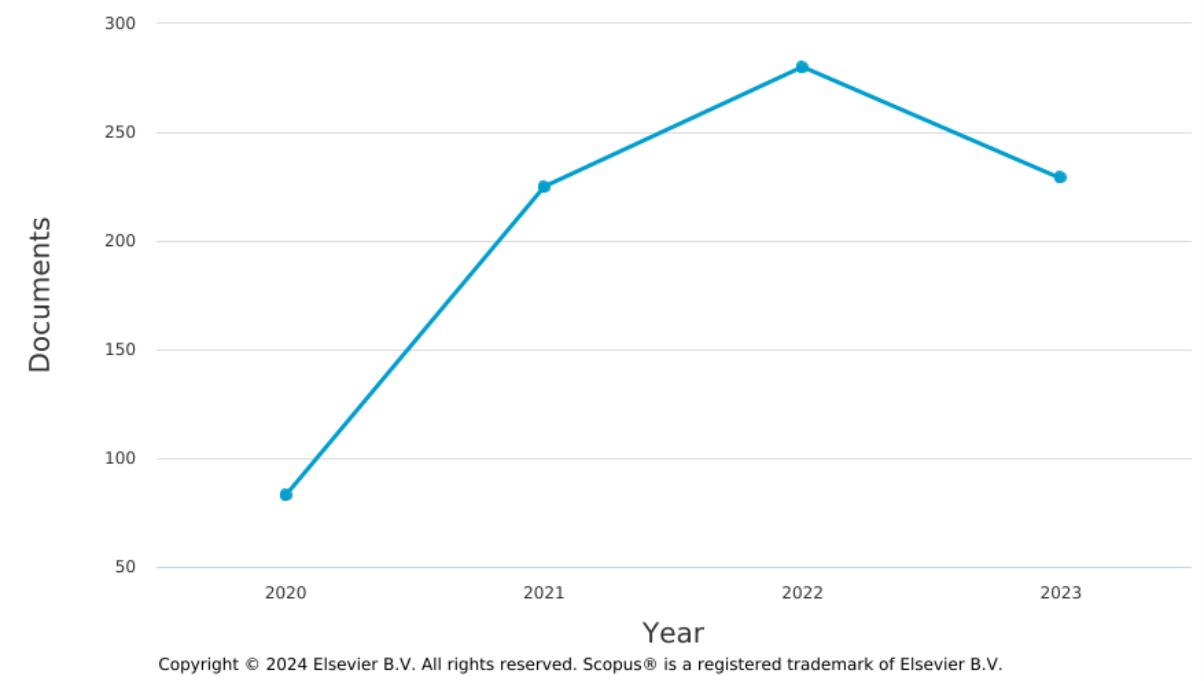

Figure 1: Number of Document Publication by Years.

RQ 2: Which Countries Have Published The Highest Number Of Documents?

The analysis of Scopus documents in figure 2 presents interesting insights into the volume of COVID-19 detection research being conducted across various countries. India, China, and the Saudi Arabia are the top three countries in terms of documents published. This is in line with expectations, given the large populations and prominent research institutions in these countries. India's top position with over 240 documents is particularly notable. The country's research output reflects both its large population, which was heavily affected by COVID-19, and its strong presence in technology and computer science research. It is likely that Indian research institutions swiftly mobilised to study COVID-19 detection using deep learning techniques.

With around 160 documents, China closely follows behind. Since China was the initial epicentre of the pandemic, it is not surprising that Chinese researchers focused heavily on COVID-19 detection research. Furthermore, China's expertise in deep learning allowed for the rapid development of detection models. Saudi Arabia holds the third spot with approximately 110 documents, following behind China and India. However, the figure also emphasizes significant contributions from other countries such as the United States, Turkey, Egypt, the United Kingdom, Pakistan, South Korea, and Iran.

This illustrates how the global research community is united in their aim to utilise advanced computational techniques such as deep learning to fight the COVID-19 pandemic. Substantial funding in biomedical research and top-tier universities with sophisticated computing capabilities have facilitated the use of deep learning for COVID-19 detection. In general, this data highlights the extensive endeavours and advancements being made internationally to enhance COVID-19 detection through AI.

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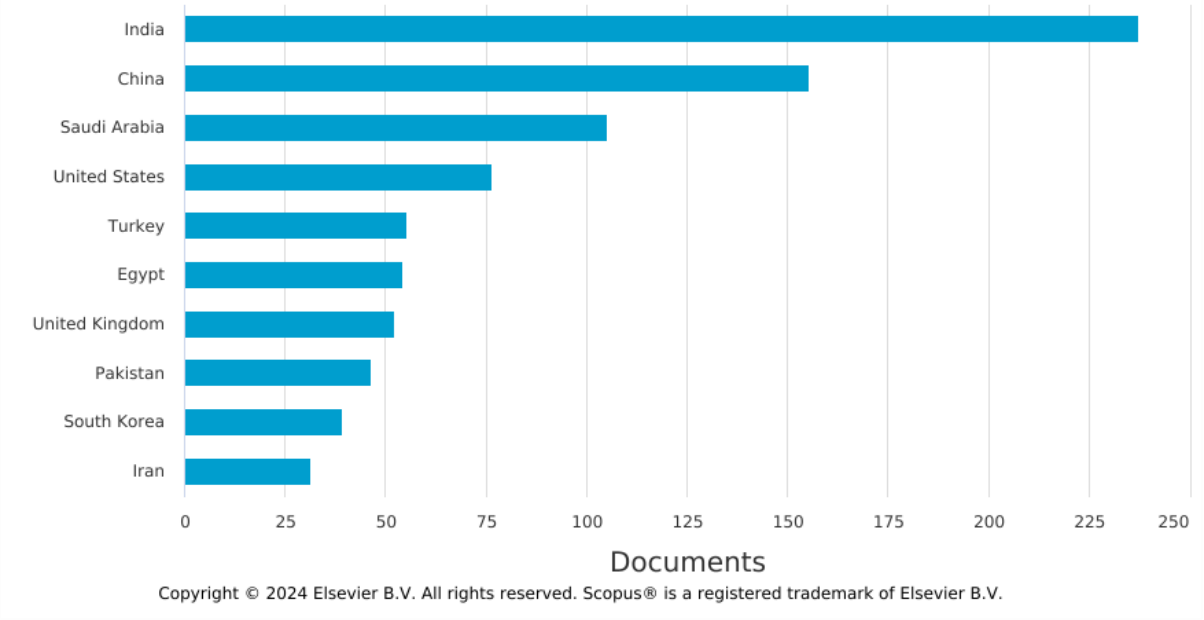

Figure 2: Number of Document Publication by Countries.

RQ 3: What Are The Different Types Of Documents Categorised By The Subject Of Research?

According to figure 3 from Scopus database, the distribution of journal articles across various scientific disciplines reveals the predominance of Computer Science, making up 27.6% of the publications, followed by Engineering at 20.7%. This distribution mirrors the current research landscape, with technological fields experiencing rapid growth driven by advancements in areas such as artificial intelligence, data analytics, and computational modelling. The significant share of Medicine, which accounts for 9.9%, emphasizes the interdisciplinary nature of modern research. This is where technological advancements are being incorporated into medical research, potentially including applications such as deep learning for diagnostic imaging. The chart also shows a substantial portion categorized as 'Other', making up 10.9%, indicating a diverse range of emerging and specialized fields that may not fit traditional disciplinary classifications.

The diversity within the research community is vital for nurturing innovative cross-disciplinary studies, which have the potential to produce breakthroughs at the crossroads of established domains. The data suggests that collaborating across multiple disciplines and investing in these leading fields could be instrumental in driving scientific progress and addressing complex global challenges.

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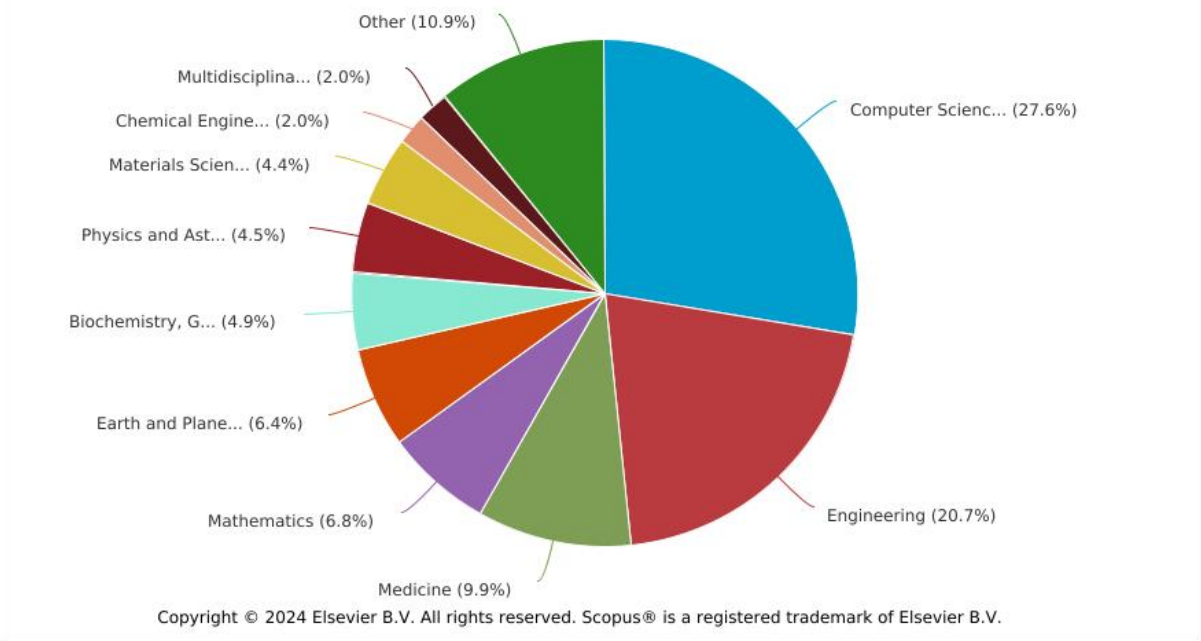

Figure 3: Types of Documents Based on Research.

RQ 4: Who Are The Top 10 Authors Based On Citation By Research?

The most cited work by Ismael A.M. and Şengür A., as shown in Table 3, has accumulated 463 citations, signifying its influential status in the field. This study has resonated with the research community, potentially establishing a benchmark for subsequent studies. The top-cited articles are published in various journals, indicating interdisciplinary interest and the wide applicability of Deep Learning techniques in medical imaging and diagnosis.

In 2020, many articles were published in response to the COVID-19 pandemic, showing a quick reaction from the scientific community to utilize AI frameworks for addressing urgent health issues. The journals 'Expert Systems with Applications' and 'Chaos, Solitons and Fractals' were notable platforms for sharing impactful research, indicating their openness to innovative computational medicine approaches. The range of citations, from 267 to 463, suggests varying levels of influence, possibly due to factors like the novelty of the approach, the strength of the results, and the early publication timing in relation to the pandemic's onset. The focus of these studies is primarily on using deep learning models to detect COVID-19 from chest X-ray and CT images, indicating a shift towards non-invasive and rapid diagnostic methods. The high number of citations highlights the significance of these studies in advancing COVID-19 research and the broader use of artificial intelligence in medical diagnostics.

Deep learning has emerged as a powerful tool for automatically analysing medical images to detect COVID-19, with some studies receiving over 400 citations. Most approaches utilize or modify standard CNN architectures with X-ray or CT images. Explainable AI and multi-task learning are also becoming prominent trends in this field. The substantial citation counts underscore the importance and impact of AI in timely COVID-19 diagnosis.

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Table 3: Top 10 Authors Based on Citation by Research

Authors	Title	Year	Source Title	Cited by
Ismael & Şengür, 2021	Deep learning approaches for COVID-19 detection based on chest X-ray images	2021	Expert Systems with Applications	463
Panwar, Gupta, Siddiqui, Morales-Menendez, & Singh, 2020	Application of deep learning for fast detection of COVID-19 in X-Rays using nCOVnet	2020	Chaos, Solitons and Fractals	436
Brunese et al., 2020	Explainable Deep Learning for Pulmonary Disease and Coronavirus COVID-19 Detection from X-rays	2020	Computer Methods and Programs in Biomedicine	399
Toğaçar et al., 2020	COVID-19 detection using deep learning models to exploit Social Mimic Optimization and structured chest X-ray images using fuzzy color and stacking approaches	2020	Computers in Biology and Medicine	395
Roy et al., 2020	Deep Learning for Classification and Localization of COVID-19 Markers in Point-of-Care Lung Ultrasound	2020	IEEE Transactions on Medical Imaging	392
Amyar et al., 2020	Multi-task deep learning based CT imaging analysis for COVID-19 pneumonia: Classification and segmentation	2020	Computers in Biology and Medicine	325
Jain et al., 2021	Deep learning based detection and analysis of COVID-19 on chest X-ray images	2021	Applied Intelligence	313
Loey et al., 2021	Fighting against COVID-19: A novel deep learning model based on YOLO-v2 with ResNet-50 for medical face mask detection	2021	Sustainable Cities and Society	296
Panwar, Gupta, Siddiqui, Morales-Menendez, Bhardwaj, et al., 2020	A deep learning and grad-CAM based color visualization approach for fast detection of COVID-19 cases using chest X-ray and CT-Scan images	2020	Chaos, Solitons and Fractals	292
Hu et al., 2020	Weakly Supervised Deep Learning for COVID-19 Infection Detection and Classification from CT Images	2020	IEEE Access	267

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RQ 5: What Are The Maps Of Co-Authorship Concerning The Deep Learning For COVID-19 Detection?

The network visualization map, created using VOSviewer and shown in the figure 4, provides a visually striking representation of the co-authorship patterns within the field of Deep Learning applications for COVID-19 detection. This map serves as a bibliometric tool, offering a clear overview of the collaborative relationships between researchers, institutions, and countries, and revealing the clustering of intellectual communities in this specialized area of research. The visualization uses different colours to distinguish between various research communities, with larger nodes representing central authors who have likely made significant contributions to the field. For example, prominent nodes such as "jain (2021a)", "hu (2020)", and "roy (2020)" indicate the presence of influential authors who serve as key figures within their respective clusters. The size of each node reflects the number of connections the author has within the network, indicating their influence and centrality. The lines between nodes represent co-authorship links, with thicker lines suggesting stronger collaborative relationships or more frequent interactions between authors.

Most of the work included in this co-authorship map was published in 2020 and 2021, reflecting the increased research activity in response to the global COVID-19 pandemic. During this time, the scientific community urgently sought to use deep learning techniques for the rapid and accurate detection of COVID-19 from medical imaging data, genomic data, and other relevant healthcare datasets. The map offers insights into how the research community evolved during this time and how new partnerships may have been formed as a result of the pandemic. In essence, this co-authorship map visually represents collaboration patterns in this research domain, showing how scientific progress is driven through networked contributions, with prolific authors, bridging authors, and institutional hubs playing central roles in connecting different groups and advancing the field.

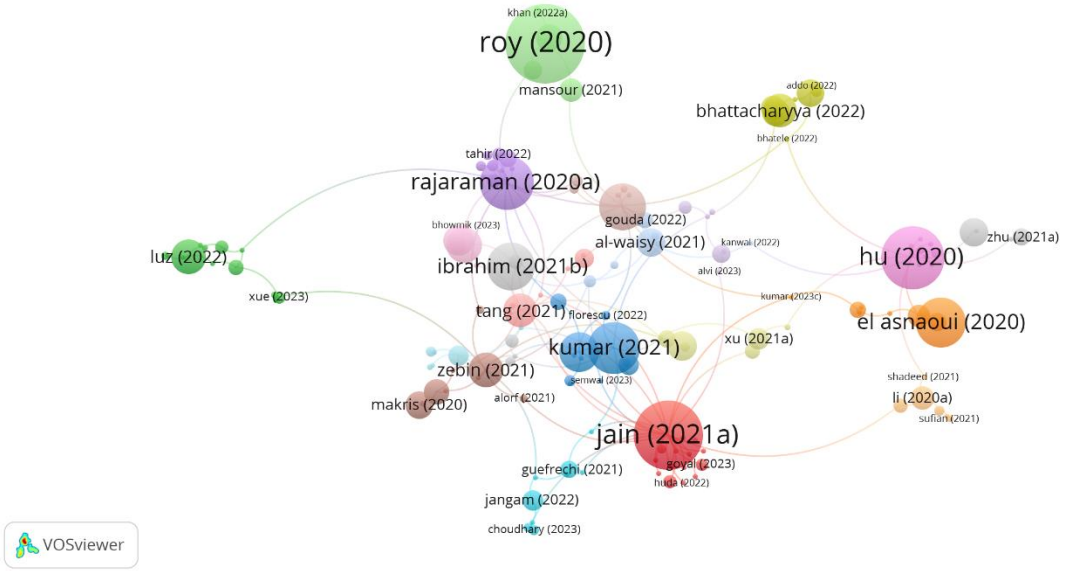

Figure 4: Network Visualization Map of Co-Authorship

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RQ 6: What Are The Popular Keywords Related To The Study?

The provided image in figure 5 is a network visualization map created using VOSviewer, a tool commonly used for bibliometric analysis. These visualizations help to identify and analyse the main themes and patterns within a large set of scientific literature. In this case, the map has been generated to show the interconnectedness and frequency of key terms used in literature related to deep learning and COVID-19 detection. At the centre of the visualization is the term "deep learning," which is closely connected to "COVID-19," indicating a significant amount of research focusing on applying deep learning techniques to detect and analyse COVID-19. The prominence of terms like "image classification," "feature extraction," "artificial intelligence," and various neural network architectures (e.g., "resnet," "alexnet," "vgg") suggests a strong emphasis on image analysis within the research. This aligns with the practical application of deep learning in interpreting medical images, such as CT scans and X-rays, to identify markers indicative of COVID-19, as supported by the appearance of related terms like "radiography" and "computed tomography."

Deep learning is closely linked to various applications and methodologies in AI, including "data augmentation," which is essential for improving machine learning models' performance, especially when dealing with limited or imbalanced training data. The presence of "segmentation" and "image segmentation" indicates a focus on dividing digital images into segments to simplify image analysis, particularly in medical image processing. The map also shows "covid19" and "pneumonia" in proximity, reflecting research into using deep learning to differentiate COVID-19 from other types of pneumonia, given their similar radiographic presentations. Overall, this network visualization map not only represents the current state of research but also helps identify critical areas of investigation, interdisciplinary connections, and potential gaps in the literature.

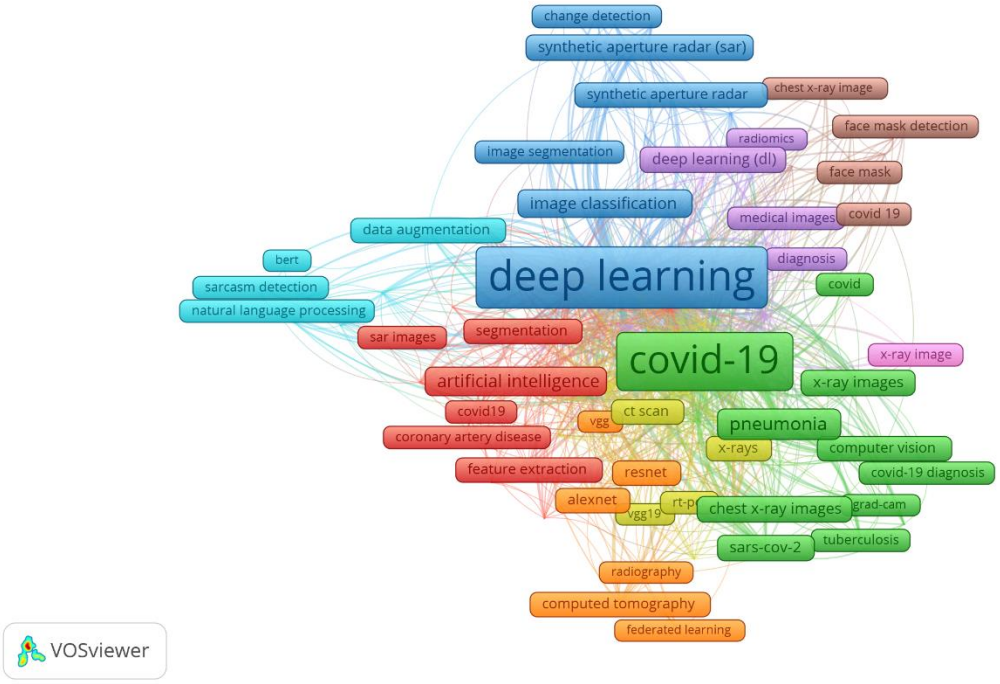

Figure 5: Network Visualization Map of Keywords' Co-Occurrence.

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RQ 7: What Are The Collaborative Countries Of Co-Authorship?

The map in Figure 6 displays the collaboration between countries in e-learning research. It shows the international network of collaboration on COVID-19 and deep learning research, with the size of each country's node representing the number of publications. The thickness of the lines between countries indicates the strength of collaboration. The United States, China, and India have the highest number of publications, with the US and China showing the strongest collaboration. Despite having fewer publications, India has formed collaborations with countries around the world, particularly with Saudi Arabia.

The network also includes strong representation from other Asian countries such as South Korea, Japan, Singapore, Taiwan, and Malaysia, in addition to Western countries like the UK, Canada, and Australia. This demonstrates the global reach and significance of COVID-19 research using deep learning techniques. The density of the network suggests that international collaboration has been essential for progress in this field. As deep learning for medical applications continues to advance, it is likely that these global research partnerships will continue to expand.

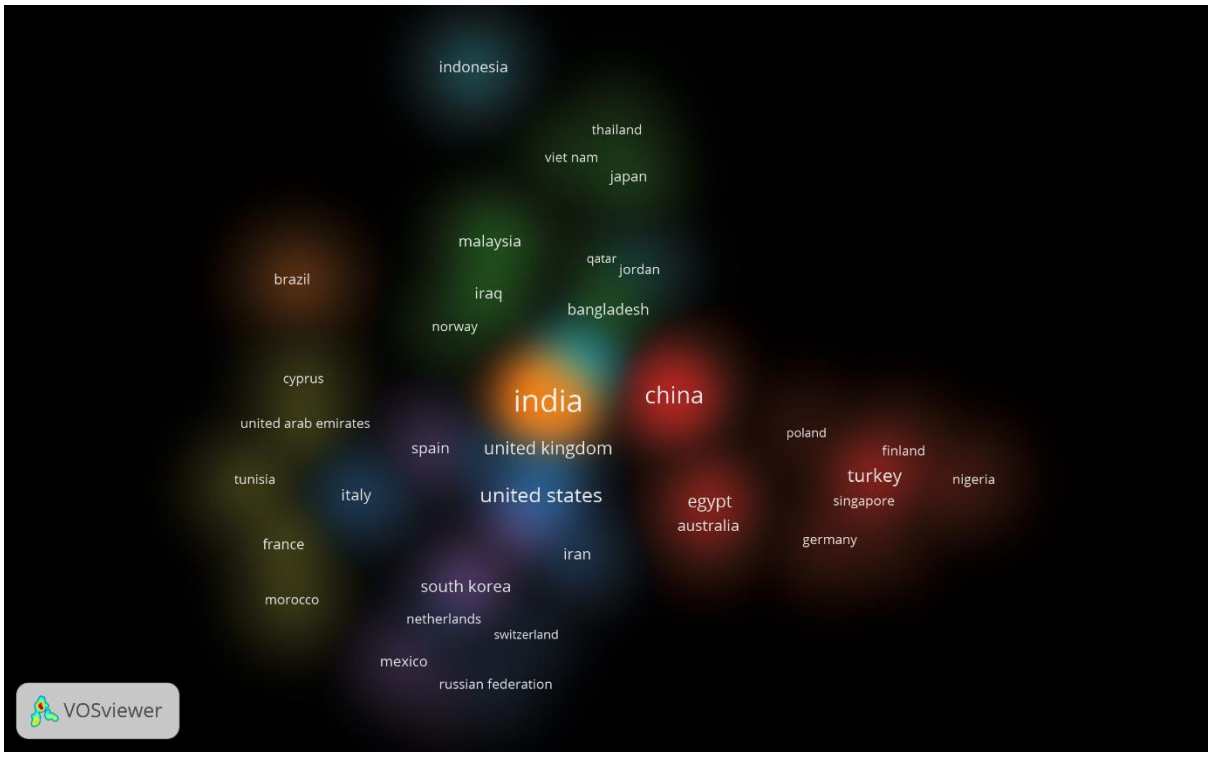

Figure 6: Network Mapping of Co-Authorship Countries' Collaboration

Discussion and Conclusion

The figure 1 above shows the trend in the number of documents published from 2020 to 2023, sourced from the Scopus database. The decline in research publication rates could be attributed to various factors, including a consolidation phase in the research topic, a change in research focus, or external factors impacting publication rates, such as the natural resolution of a pandemic or the reallocation of funding and resources to other areas. The insights from the analysis of Scopus documents in figure 2 reveal fascinating trends in the amount of COVID-

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19 detection research being carried out in different countries. China's proficiency in deep learning has enabled the swift creation of detection models. Saudi Arabia ranks third with around 110 documents, trailing behind China and India. This highlights the global research community's shared goal of harnessing advanced computational methods like deep learning to combat the COVID-19 pandemic. Based on the data provided in figure 3 of Scopus, most journal articles are found in the field of Computer Science, accounting for 27.6% of the publications, with Engineering following closely at 20.7%. This distribution reflects the current research environment, where technological disciplines are expanding rapidly due to progress in artificial intelligence, data analytics, and computational modelling.

In response to the COVID-19 pandemic in 2020, the scientific community quickly turned to AI frameworks to address urgent health issues, leading to the publication of numerous articles. Notably, the journals 'Expert Systems with Applications' and 'Chaos, Solitons and Fractals' served as platforms for sharing impactful research, demonstrating their openness to innovative computational medicine approaches. These studies primarily focused on using deep learning models to detect COVID-19 from chest X-ray and CT images, signalling a shift towards non-invasive and rapid diagnostic methods. The high number of citations for these studies underscores their significance in advancing COVID-19 research and the broader use of artificial intelligence in medical diagnostics. The visualization in figure 4 employs a colour-coded system to differentiate between different research communities, using larger nodes to represent influential authors who have made significant contributions to the field. The size of each node is indicative of the author's influence and centrality within the network, based on the number of connections they have. Most of the research included in this co-authorship map was published in 2020 and 2021, reflecting the heightened research activity in response to the global COVID-19 pandemic. This map provides valuable insights into the evolution of the research community during this period and how new partnerships may have emerged because of the pandemic.

The network visualization map in figure 5 was generated using VOSviewer, a popular tool for bibliometric analysis. The clustering of "segmentation" and "image segmentation" suggests a concentration on the partitioning of digital images into segments for the purpose of streamlining image analysis, particularly in the field of medical image processing. Additionally, the map reveals the proximity of "covid19" and "pneumonia," indicating a focus on utilizing deep learning to distinguish COVID-19 from other forms of pneumonia, given their similar radiographic presentations. The collaboration between countries in e-learning research is depicted in Figure 6's map. The United States, China, and India have the highest number of publications, and the US and China exhibit the strongest collaboration.

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