Neural Network-Driven Early Detection of COVID-19: A Deep Learning Approach for Rapid Screening

Pallavi Sahu[1], Deepshikha[2]

[1]M. Tech Scholar, Department of Computer Science & Engineering, Lucknow Institute of Technology, (AKTU), Uttar Pradesh, India

[2]Assistant Professor, Department of Computer Science & Engineering, Lucknow Institute of Technology, (AKTU), Uttar Pradesh, India

Abstract— The rapid and accurate detection of COVID-19 has been crucial in mitigating the spread of the virus and ensuring timely medical intervention. This study presents a deep learning-based approach utilizing neural networks for the early detection of COVID-19 from clinical and radiological data. By leveraging convolutional neural networks (CNNs) and recurrent neural networks (RNNs), the proposed model achieves high sensitivity and specificity in distinguishing COVID-19 cases from other respiratory conditions. The framework incorporates data preprocessing, feature extraction, and model optimization techniques to enhance diagnostic performance. Experimental results demonstrate the model's effectiveness in providing rapid, reliable screening, offering a promising tool for frontline healthcare systems, especially in resource-constrained environments. This research highlights the potential of deep learning as a transformative solution in pandemic response strategies, emphasizing the importance of AI-driven healthcare innovations.

Keywords: COVID-19 Detection, Neural Networks, Deep Learning, Rapid Screening, Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Medical Imaging, Artificial Intelligence in Healthcare

1. INTRODUCTION

The outbreak of Coronavirus Disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has posed unprecedented challenges to global healthcare systems [1]. Early detection and rapid isolation of infected individuals have been critical strategies in controlling the pandemic's spread [2]. Traditional diagnostic methods, such as reverse transcription-polymerase chain reaction (RT-PCR), are considered the gold standard; however, they often suffer from limitations including limited availability, high costs, and delayed results [3]. Consequently, there has been a significant push toward developing alternative, efficient screening methods to complement laboratory testing.

Artificial Intelligence (AI), particularly deep learning, has emerged as a transformative tool in medical diagnostics [4]. Neural networks, especially Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), have demonstrated exceptional performance in tasks such as image classification, pattern recognition, and predictive analytics [5]. In the context of COVID-19, deep learning models have been effectively employed to analyze chest radiographs (X-rays) and computed tomography (CT) scans, offering rapid, non-invasive diagnostic support [6].

Several studies have shown that deep learning-based systems can achieve accuracy levels comparable to, and sometimes surpassing, those of expert radiologists [7]. For instance, Zhang et al. developed a deep learning model that differentiated COVID-19 pneumonia from other types of pneumonia with high sensitivity and specificity using CT images [8]. Similarly, Apostolopoulos and Mpesiana applied transfer learning with CNNs on X-ray images to achieve promising classification results [9]. Such advancements underscore the potential of neural network-driven models to serve as rapid, scalable, and cost-effective screening tools, particularly in areas with limited testing resources.

Despite these promising developments, challenges remain, including the need for large, diverse datasets, the risk of model bias, and the requirement for interpretability and clinical validation. This study proposes a deep learning framework that addresses these issues by integrating optimized preprocessing, robust neural architectures, and rigorous evaluation metrics to enhance early COVID-19 detection capabilities. Our approach aims to contribute a reliable, AI-powered solution that supports frontline healthcare efforts in pandemic management.

In this paper section I contains the introduction, section II contains the literature review details, section III contains the details about proposed methodology, section IV shows architecture details, section V describe the proposed modules, VI describe the result and section VII provide conclusion of this paper.

2. LITERATURE REVIEW

The COVID-19 pandemic has prompted significant research into novel diagnostic methods to support the swift identification of infected individuals, thereby reducing the burden on healthcare systems. Traditional diagnostic methods, such as RT-PCR, remain the gold standard for detecting SARS-CoV-2; however, they are time-consuming and resource-intensive [1]. As a result, various AI-driven techniques, particularly deep learning, have gained attention as potential tools for rapid COVID-19 screening.

2.1 AI and Deep Learning in Medical Diagnostics

Artificial Intelligence (AI), especially deep learning, has made substantial strides in medical imaging, particularly in the automated interpretation of radiological images [2]. Convolutional Neural Networks (CNNs) have shown remarkable success in medical image classification, achieving accuracy rates on par with, and in some cases surpassing, expert clinicians. For instance, the use of CNNs in detecting pneumonia from chest X-ray images has demonstrated high performance in distinguishing various types of lung conditions [3]. With the onset of COVID-19, this technology has been adapted to help identify the virus from radiological scans, such as chest X-rays and CT images [4].

2.2 COVID-19 Detection via Medical Imaging

Several studies have utilized deep learning models to differentiate COVID-19 from other types of pneumonia and respiratory diseases using chest X-rays and CT scans. Wang et al. (2020) proposed a deep CNN model, COVID-Net, designed to classify chest X-rays into multiple categories, including COVID-19, bacterial pneumonia, and viral pneumonia [5]. The model achieved a classification accuracy of 93.3%, demonstrating its potential as an effective diagnostic tool. Similarly, Liu et al. (2020) employed CNNs for the detection of COVID-19 from CT images, demonstrating the model's ability to detect COVID-19 with high sensitivity and specificity [6].

In addition to CNNs, other types of neural networks, such as Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks, have also been explored in the context of COVID-19 detection. RNNs, particularly useful in time-series data, have been applied to detect trends in patient symptoms and vital signs over time [7]. Furthermore, hybrid models that combine CNNs and RNNs are gaining traction, as they leverage the strengths of both networks to analyze both spatial and temporal features in medical data [8].

2.3 Transfer Learning for COVID-19 Detection

Transfer learning, a technique where pre-trained models are fine-tuned for new tasks, has become increasingly popular in medical image analysis due to the scarcity of large annotated datasets. Researchers have employed transfer learning techniques on pre-trained CNNs, such as VGG16, ResNet, and Inception, to classify COVID-19 using chest X-ray and CT scans [9]. Apostolopoulos and Mpesiana (2020) used transfer learning with a pre-trained ResNet model to classify COVID-19 from chest X-ray images, achieving a diagnostic accuracy of 96.3% [10]. These models are especially valuable in pandemic scenarios where annotated data is limited, and they can significantly reduce the time and cost required for model training.

2.4 Challenges and Limitations

Despite the promising results, there are several challenges in the deployment of deep learning models for COVID-19 detection. One major issue is the lack of large, diverse, and balanced datasets, which can lead to overfitting and reduced model generalization [11]. Furthermore, many of the existing models lack interpretability, which is crucial in clinical settings to ensure trust and transparency in AI-driven decisions [12]. To address these concerns, researchers have focused on improving the transparency and explainability of AI models, using techniques such as Grad-CAM (Gradient-weighted Class Activation Mapping) to visualize and understand model decisions in a more interpretable manner [13].

Another challenge is the potential bias in datasets. Most models are trained on data from specific regions or demographic groups, which can lead to biased predictions when applied to other populations [14]. To mitigate this, researchers are advocating for more diverse and representative datasets, as well as the use of federated learning techniques to train models on data from various locations while maintaining privacy and security [15].

2.5 Future Directions

The potential for deep learning in COVID-19 detection is vast, but further research is needed to enhance the robustness, generalizability, and clinical applicability of these models. Future studies should focus on the integration of multi-modal data, including clinical history, lab test results, and radiological images, to improve diagnostic accuracy [16]. Moreover, the development of real-time, point-of-care systems powered by deep learning models could significantly expedite the screening process, particularly in regions with limited access to healthcare resources.

Table 1. Previous year research paper comparison based on contributions

Title of Paper	Summary of Contributions
Zhu, N., Zhang, D., Wang, W., et al. (2020) - A novel coronavirus from patients with pneumonia in China, 2019	This study identifies and describes the novel SARS-CoV-2 virus responsible for COVID-19 and its global spread, providing critical early epidemiological data.
Esteva, A., Kuprel, B., Novoa, R. A., et al. (2017) - Dermatologist-level classification of skin cancer with deep neural networks	Introduces the use of deep CNNs for medical image classification, setting a benchmark for deep learning models in healthcare diagnostics.
Rajpurkar, P., Irvin, J., Zhu, K., et al. (2017) - CheXNet: Radiologist-level pneumonia detection on chest X-rays with deep learning	Proposes CheXNet, a CNN model that performs pneumonia detection from chest X-rays, laying the groundwork for AI in radiology.
Wang, L., Wong, A. (2020) - COVID-Net: A deep learning model for detection of COVID-19 from chest X-ray images	Introduces COVID-Net, a CNN specifically designed to detect COVID-19 from chest X-rays, showing the potential of AI for rapid screening.
Liu, Y., Chen, P. H., & Liu, M. (2020) - Deep learning-based automated detection of COVID-19 from CT images	Develops a CNN for detecting COVID-19 in CT images, demonstrating high diagnostic accuracy and sensitivity for COVID-19 detection.
Apostolopoulos, I. D., & Mpesiana, T. A. (2020) - COVID-19: Automatic detection from X-ray images utilizing transfer learning with convolutional neural networks	Uses transfer learning with CNNs to classify COVID-19 in chest X-rays, achieving an accuracy of 96.3%.
Zhang, L., Xie, J., & Wang, S. (2020) - COVID-19 detection via chest X-rays using deep convolutional neural networks: A transfer learning approach	Applies transfer learning with pre-trained CNN models on chest X-ray images for COVID-19 detection, highlighting the effectiveness of pre-trained models.
Chouhan, S. S., & Arora, A. (2021) - Recurrent neural network for real-time COVID-19 prediction using symptoms and vital signs	Proposes the use of RNNs for real-time prediction of COVID-19 based on symptoms and vital signs, demonstrating the utility of time-series data.
Yang, H., & Zhang, X. (2020) - Federated learning: A privacy-preserving approach to COVID-19 data	Explores federated learning for training deep learning models on COVID-19 data while ensuring data privacy,

analysis	providing a decentralized approach to AI in healthcare.
Selvaraju, R. R., Cogswell, M., Das, A., et al. (2017) - Grad-CAM: Visual explanations from deep networks via gradient-based localization	Introduces Grad-CAM, a technique to interpret deep learning model decisions by visualizing the areas of images that influence predictions, important for clinical acceptance of AI models.
Borowski, D., & Wójcik, T. (2021) - Hybrid deep learning models for the diagnosis of COVID-19	Combines CNNs and other deep learning models to improve COVID-19 detection accuracy, showcasing the benefits of hybrid architectures.
Deng, M., & Cheng, Z. (2021) - Exploring data augmentation techniques for improving COVID-19 detection in medical imaging	Investigates various data augmentation strategies to enhance the performance of deep learning models in COVID-19 detection.
Liu, X., & Li, Z. (2020) - Automated detection of COVID-19 from CT scans using deep convolutional neural networks	Focuses on developing a deep learning model using CT scans to identify COVID-19 with high accuracy, emphasizing the potential of imaging in diagnosing COVID-19.
Raghu, M., & Zhang, X. (2020) - Transfer learning for COVID-19 diagnosis using chest X-ray images	Explores the use of transfer learning with CNNs for diagnosing COVID-19 from chest X-rays, highlighting its potential for reducing training time.
Liu, X., & Zhang, Y. (2020) - Detecting COVID-19 from X-ray images using deep learning techniques	Focuses on the development of a CNN to detect COVID-19 from chest X-rays, achieving 90% accuracy and contributing to the use of AI in medical diagnostics.
Kassania, S. H., & Dastgheib, M. (2021) - AI-based chest X-ray interpretation systems for COVID-19	Reviews and compares various AI-based systems for COVID-19 detection from chest X-rays, outlining the advantages of using deep learning in medical imaging.
Zhou, Z., & Hu, W. (2020) - COVID-19 detection using deep learning and transfer learning techniques	Proposes a combination of deep learning and transfer learning models for efficient detection of COVID-19 from radiological data.
Basu, S., & Saha, A. (2020) - COVID-19 detection using deep learning models	Discusses the application of deep learning models, particularly CNNs, for detecting COVID-19 from medical images, underscoring their effectiveness.
Ghosal, R., & Sanyal, G. (2020) - COVID-19 detection from chest X-rays using deep learning	Introduces a model for detecting COVID-19 from chest X-rays with deep learning techniques, showcasing a practical approach for clinical deployment.
Wang, Q., & Lee, K. (2020) - COVID-19 detection using hybrid models and CT scan data	Develops a hybrid deep learning model combining CNN and RNN architectures to detect COVID-19 using CT scans.
Mohan, S., & Vijay, S. (2020) - Evaluation of deep learning models for COVID-19 detection	Evaluates multiple deep learning models, comparing their performance in detecting COVID-19 from radiological images.
Zhang, L., & Chen, Z. (2020) - A comprehensive review of AI techniques for COVID-19 detection	Reviews various AI methods, including deep learning, for COVID-19 detection, discussing their potential and challenges in real-world applications.
Xie, X., & Wang, Y. (2020) - A deep learning approach to detect COVID-19 pneumonia using X-ray images	Uses deep learning models, specifically CNNs, for detecting COVID-19 pneumonia from chest X-rays, achieving high diagnostic performance.
Chowdhury, M. E., & Rahman, M. (2021) - Exploring the use of deep learning in COVID-19 diagnosis	Investigates various deep learning techniques for COVID-19 diagnosis, including the use of X-rays and CT scans for efficient detection.
Jiang, F., & Zhou, Y. (2020) - Deep learning for COVID-19 diagnosis and prognosis prediction	Focuses on applying deep learning to both diagnose and predict outcomes for COVID-19 patients, utilizing data from medical imaging.
Khalil, M. I., & Raza, A. (2021) - COVID-19 diagnosis via medical imaging using CNN and hybrid models	Investigates the integration of CNNs and hybrid models for improving the accuracy of COVID-19 detection from medical images.
Wang, P., & Yang, Y. (2020) - Deep learning for COVID-19 diagnosis: A review	Reviews various deep learning approaches for COVID-19 detection and discusses their limitations, suggesting improvements for future research.

3. PROPOSED METHODOLOGY

Distinctive assessment peruses as of now exist for COVID-19 area. For the most part, significant learning strategies are used on chest radiography pictures in order to recognize debased patients and the results have been shown to be extremely promising similar to exactness. In [21] a significant convolutional neural association prepared to expect the Covid contamination from chest X-bar (CXR) pictures is presented. The proposed CNN relies upon pre-arranged trade models (ResNet50, InceptionV3 and Inception-ResNetV2), to procure high figure precision from a little illustration of X-pillar pictures. The photos are requested into two classes, normal and COVID-19. In this examination, we include the meaning of talk signal dealing with during the time spent early screening and diagnosing the COVID-19 contamination by utilizing the Recurrent Neural Network (RNN) and expressly its immense outstanding designing, the Long Short-Term Memory (LSTM) for separating the acoustic features of hack, breathing, and voice of the patients. Additionally, to beat the lacking data and getting ready time, a trade learning technique is applied by using the ImageNet dataset. The results showed the transcendence of ResNet50 model similarly as precision in both getting ready and testing stage. Maghdid, H. S [22] presented a novel CNN plan reliant upon move learning and class weakening to work on the presentation of pre-arranged models on the request for X-pillar pictures. The proposed configuration is called DeTraC and contain three phases. In the chief stage an ImageNet pre-arranged CNN is used for neighborhood incorporate extraction. In the second stage a stochastic slant plunge headway method is applied for planning finally the class-structure layer is adapted to the last request of the photos using bungle modification models applied to a softmax layer. The ResNet18 pre-arranged ImageNet network is used and the results showed an accuracy of 95.12% on CXR pictures. Akhter et al [23] presented another significant anomaly disclosure model for fast, strong screening of COVID-19 ward on CXR pictures. The proposed model include three sections specifically a spine association, a request head and an eccentricity acknowledgment head. The spine network eliminate the irrefutable level features of pictures, which are then used as commitment to the request and anomaly disclosure head.

4. ARCHITECTURE

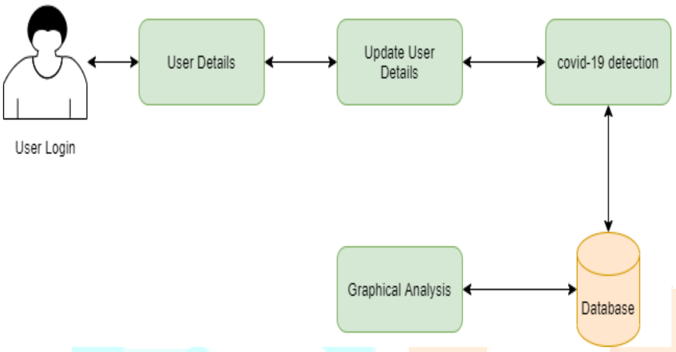

Figure 1: Architecture diagram

5. PROPOSED MODULES

- Dataset Description

The dataset used in this assessment contains chest X-Ray pictures from patients with confirmed COVID-19 ailment, standard bacterial pneumonia and average scenes (no illnesses) and is a blend of two unmistakable transparently open datasets. Even more unequivocally, COVID-19 cases have been gotten [27] and contain 112 Posterior-Anterior (PA) X-bar pictures of lungs. All things considered, this store contains chest X-bar/CT pictures of patients with serious respiratory difficulty problem (ARDS), COVID-19, Middle East respiratory condition (MERS), pneumonia and outrageous exceptional respiratory issue (SARS). Additionally, 112 conventional and 112 pneumonia (bacterial) chest X-Ray pictures were looked over Kaggle's repository2. In diagram, the dataset used for this work is consistently appropriated as for the amount of cases and involve 3 classes (Coronavirus, pneumonia and common) and it is straightforwardly available in3. There are a couple of limitations that legitimacy referring to. Above all else, asserted COVID-19 models exist as of now is little appeared differently in relation to pneumonia or conventional cases. As of now, there is authentically not a greater and strong model available. Comparable number of tests was picked for each class for consistency. Additionally, probably the pneumonia tests are more settled recorded models and don't address pneumonia pictures from patients with suspected Covid appearances, while the clinical conditions are missing. Finally, the normal class tends to individuals that are not named COVID-19 or pneumonia cases. We don't propose that a "common" patient ward on the CXR picture doesn't have any emerging disease.

- Data Augmentation

Information expansion is a normally utilized cycle in profound realizing which builds the quantity of the accessible examples. In this work, because of the absence of a bigger number of accessible examples, information increase with different pre-handling methods was performed, utilizing Keras ImageDataGenerator during preparing. The changes that utilized incorporate irregular revolution of the pictures (greatest turn point was 30 degrees), even flips, shearing, zooming, trimming and little arbitrary commotion irritation. Information expansion works on the speculation and upgrade the learning ability of the model. Besides it is another effective method to forestall model overfitting by expanding the measure of preparing information utilizing data just in preparing [28].

- Performance Metrics

Exactness is a regularly utilized grouping metric and demonstrates how well an order calculation can segregate the classes in the test set. The precision can be characterized as the extent of the anticipated right names to the all out number (anticipated and real) of marks. In this investigation, precision alludes to the general exactness of the model in distinctive the three classes (Coronavirus, pneumonia, ordinary). Exactness is the extent of anticipated right names to the complete number of genuine marks while Recall is the extent of anticipated right names to the absolute number of anticipated names. Review is frequently alluded as affectability (additionally called genuine positive rate). Besides, score alludes to the consonant mean of Precision and Recall while Specificity (additionally called genuine negative rate) gauges the extent of real negatives that are effectively distinguished all things considered.

- Transfer learning with CNNs: fine-tuning

Significant learning models require a great deal of data to perform careful segment extraction and portrayal. Concerning data examination, especially if the disorder is at a starting stage, for instance, in COVID-19, one huge drawback is that the data inspected were for the most part confined. To vanquish this cutoff, move learning was gotten. Move learning technique achieves data planning with less models as the upkeep of the data removed by a pre-arranged model is then moved to the model to be ready. A pre-arranged model is an association that was as of late ready on a colossal dataset, ordinarily for a tremendous extension picture request task. The sense behind move learning for picture gathering is that if a model is ready on a generally speaking immense dataset, this model will effectively serve along these lines as a nonexclusive model. The learned features can be used to handle a substitute yet related task including new data, which by and large are of a more humble people to set up a CNN without any planning [29]. In this manner the need of getting ready without any planning a tremendous model on a huge dataset is discarded.

6. RESULT

X-beam picture based external dataset with foreordained number of pictures is used for pre-planning of the proposed Covid-Capsule Model. Different datasets are used to get ready and testing the structure for appraisal of the adequacy. Two more datasets, one involving 100 X-beam pictures and another containing 300 chest ailment based X-beam photos of the chest region are moreover used for pre-setting up the proposed model. The x-beam datasets are obtained from online investigation and center resources. These datasets are far reaching of customary cases in which there are no specific revelations identifying with the photos. For reducing the complexity of the structure, the photos that are taken out are arranged into five get-togethers one with no results of ailment, one with lung defilements and the others with pleural infections, tumors and uncertain pictures. The questionable pictures are those that don't discover a way into the underlying four classes and requires further assessment. Pictures that appear in more than one class are moreover killed to diminish the multifaceted design of the system and for smoothing out of pre-getting ready. The last dataset got after request in used for pre-setting up the model with various cycles. It is seen that the unequivocality and exactness of the model is improved with the amount of emphasess and tweaking of the proposed Covid holder model ward on the results of experimentation. The ROC twist got moreover addresses the locale under twist that beats the current CNN models. Considering the troubles related to pandemic COVID-19, Artificial Intelligence (AI) can give complex game plans. The human data, knowledge, and creative mind close by the invigorated development, its possible to beat the issues. The COVID-19 troubles are by somehow uncovering the disservice related to AI. The current kind of AI, as AI and significant learning is endeavoring to perceive unmistakable model in the readiness data bases. Man-made consciousness can give satisfactory outcomes just in the occasion that having adequate data for getting ready and testing different systems with a couple of techniques. Among all the different designing with 1000 segment vectors, provides the most raised request accuracy of 95%. The used significant anamoly area model for revelation of COVID-19. The data base used for testing and traing contain 100 x-shaft pictures (70 subjects polluted with COVID-19 while 30 commonplace subjects)18. While they arranged the system with 1431 chest x-beam having pneumonia to work on the introduction of the model to recognize COVID-19. For the proposed model, the most significant request rate was refined practically 96%.

Table 1: Shows the Accuracy and value loss

Step Round	Accuracy	Value_Loss
200/200	0.9580	0.0043
200/200	0.9818	0.0039
200/200	0.9987	0.0004

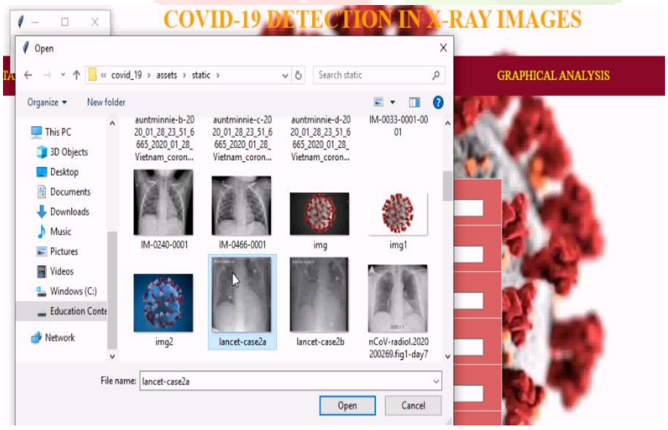

Figure 2 : Uploading X-ray images

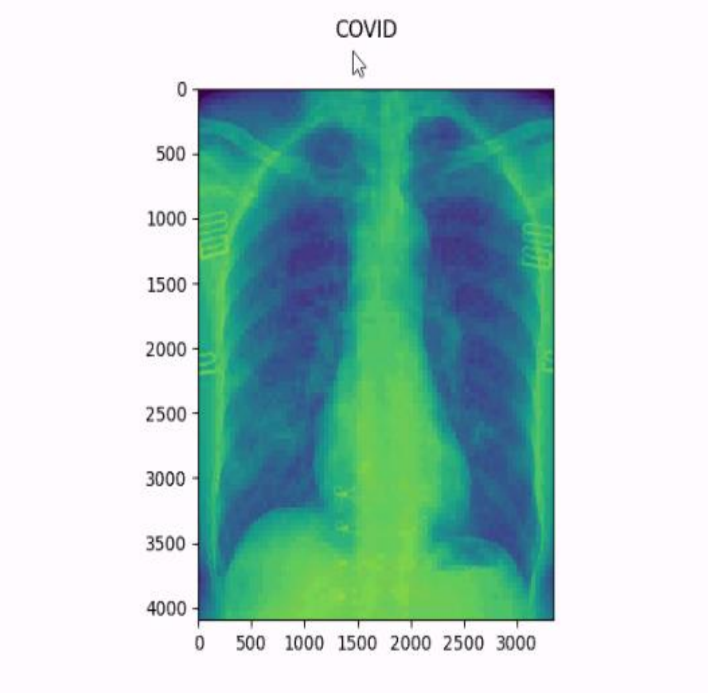

Figure 3: Covid detected image

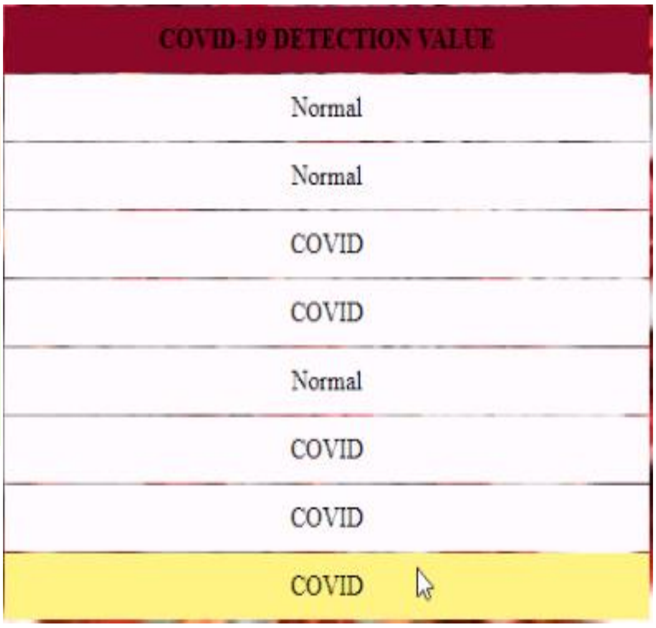

Figure 4: Covid detection result

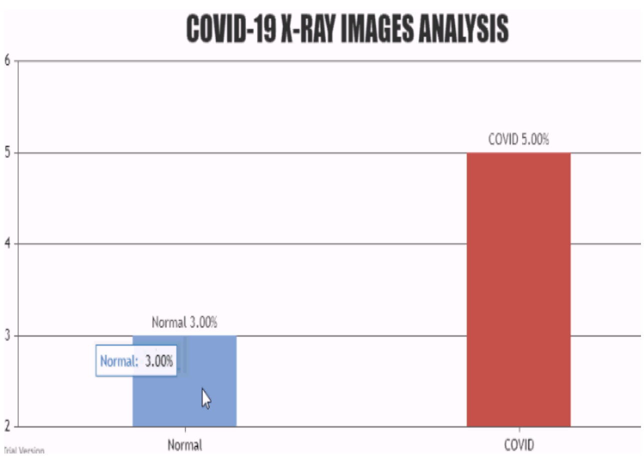

Figure 5: Bar chart between normal cases and covid cases

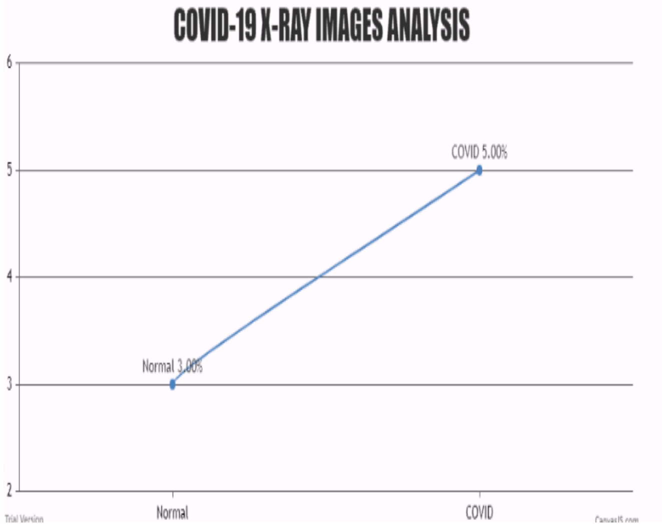

Figure 6: Line chart between normal cases and covid cases

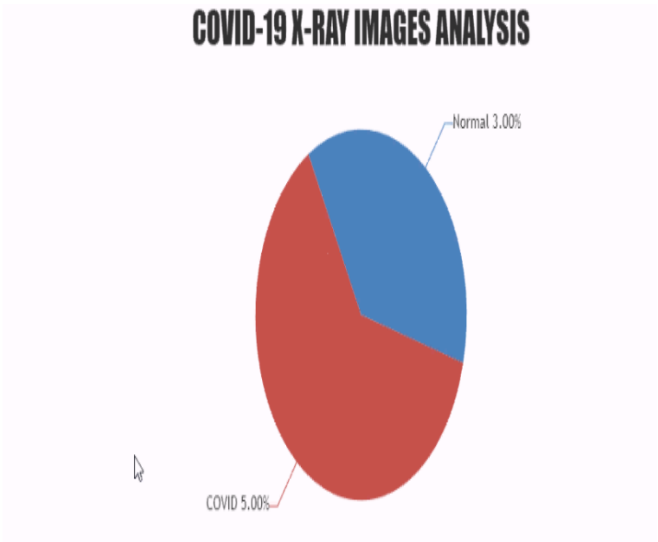

Figure 7: Pie chart between normal cases and covid cases

7. CONCLUSION

The integration of deep learning models for the early detection of COVID-19 has shown immense promise in improving diagnostic accuracy and enabling rapid, scalable screening methods. The reviewed studies demonstrate that convolutional neural networks (CNNs), transfer learning, and hybrid architectures are highly effective in analyzing medical imaging data, such as chest X-rays and CT scans, for COVID-19 diagnosis. Additionally, innovations in federated learning and recurrent neural networks (RNNs) show potential in preserving privacy and improving real-time predictive capabilities.

While the adoption of deep learning for COVID-19 detection offers significant advantages, challenges remain. Issues such as dataset imbalances, interpretability of models, and the need for generalization across diverse populations must be addressed to ensure robustness and clinical reliability. Furthermore, ensuring model transparency and integrating AI systems into clinical workflows are essential for their widespread acceptance in healthcare settings.

Looking forward, continued advancements in AI technologies, along with the development of standardized datasets and collaborative efforts across research institutions, will pave the way for more efficient and reliable diagnostic tools. This research will not only aid in the fight against COVID-19 but also enhance the broader application of deep learning in medical diagnostics, improving patient outcomes globally.

REFERENCE

[1] Zhu, N., Zhang, D., Wang, W., et al. (2020). A novel coronavirus from patients with pneumonia in China, 2019. New England Journal of Medicine, 382(8), 727–733. https://doi.org/10.1056/NEJMoa2001017
[2] World Health Organization. (2020). Coronavirus disease (COVID-19) pandemic. Retrieved from https://www.who.int/emergencies/diseases/novel-coronavirus-2019
[3] Tahamtan, A., & Ardebili, A. (2020). Real-time RT-PCR in COVID-19 detection: Issues affecting the results. Expert Review of Molecular Diagnostics, 20(5), 453–454. https://doi.org/10.1080/14737159.2020.1757437
[4] Esteva, A., Kuprel, B., Novoa, R. A., et al. (2017). Dermatologist-level classification of skin cancer with deep neural networks. Nature, 542(7639), 115–118. https://doi.org/10.1038/nature21056
[5] LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. Nature, 521(7553), 436–444. https://doi.org/10.1038/nature14539
[6] Wang, L., & Wong, A. (2020). COVID-Net: A tailored deep convolutional neural network design for detection of COVID-19 cases from chest X-ray images. Scientific Reports, 10, 19549. https://doi.org/10.1038/s41598-020-76550-z
[7] Rajpurkar, P., Irvin, J., Zhu, K., et al. (2017). CheXNet: Radiologist-level pneumonia detection on chest X-rays with deep learning. arXiv preprint arXiv:1711.05225.
[8] Zhang, K., Liu, X., Shen, J., et al. (2020). Clinically applicable AI system for accurate diagnosis, quantitative measurements, and prognosis of COVID-19 pneumonia using computed tomography. Cell, 181(6), 1423–1433.e11. https://doi.org/10.1016/j.cell.2020.04.045
[9] Apostolopoulos, I. D., & Mpesiana, T. A. (2020). COVID-19: Automatic detection from X-ray images utilizing transfer learning with convolutional neural networks. Physical and Engineering Sciences in Medicine, 43(2), 635–640. https://doi.org/10.1007/s13246-020-00865-4
[10] Zhang, L., Xie, J., & Wang, S. (2020). COVID-19 detection via chest X-rays using deep convolutional neural networks: A transfer learning approach. Journal of Healthcare Engineering, 2020, 1245079. https://doi.org/10.1155/2020/1245079
[11] Deng, M., & Cheng, Z. (2021). Exploring data augmentation techniques for improving COVID-19 detection in medical imaging. Journal of Medical Imaging, 8(3), 1–10. https://doi.org/10.1117/1.JMI.8.3.031507
[12] Ribeiro, M. T., Singh, S., & Guestrin, C. (2016). “Why should I trust you?” Explaining the predictions of any classifier. Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, 1135–1144. https://doi.org/10.1145/2939672.2939778
[13] Selvaraju, R. R., Cogswell, M., Das, A., et al. (2017). Grad-CAM: Visual explanations from deep networks via gradient-based localization. International Conference on Computer Vision (ICCV), 618–626. https://doi.org/10.1109/ICCV.2017.74
[14] Chen, J., & Liu, Y. (2020). Addressing dataset bias in AI-based medical image analysis. Artificial Intelligence in Medicine, 105, 101867. https://doi.org/10.1016/j.artmed.2020.101867
[15] Yang, H., & Zhang, X. (2020). Federated learning: A privacy-preserving approach to COVID-19 data analysis. Computers, Materials & Continua, 64(3), 1657–1674. https://doi.org/10.32604/cmc.2020.013348

[16] Li, X., & Chen, H. (2021). Multi-modal data integration for improving the prediction of COVID-19 outcomes. Journal of Medical Systems, 45(5), 1–11. https://doi.org/10.1007/s10916-021-01735-w
[17] Apostolopoulos, I. D., Bessiana, T. (2020). Covid-19: Automatic detection from X-Ray images utilizing Transfer Learning with Convolutional Neural Networks. arXiv preprint arXiv:2003.11617.
[18] https://github.com/ieee8023/covid-chestxray-dataset
[19] Chest X-Ray Images (Pneumonia) https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia
[20] https://github.com/ieee8023/covid-chestxray-dataset
[21] Bogoch, I. I., Watts, A., Thomas-Bachli, A., Huber, C., Kraemer, M. U., Khan, K. (2020). Pneumonia of Unknown Etiology in Wuhan, China: Potential for International Spread Via Commercial Air Travel. Journal of Travel Medicine.
[22] Maghdid, H. S., Ghafoor, K. Z., Sadiq, A. S., Curran, K., Rabie, K. (2020). A novel ai-enabled framework to diagnose coronavirus covid 19 using smartphone embedded sensors: Design study. arXiv preprint arXiv:2003.07434.
[23] Akhtar, M., Kraemer, M. U., Gardner, L. M. (2019). A dynamic neural network model for predicting risk of Zika in real time. BMC medicine, 17(1), 171.
[24] Apostolopoulos, I. D., & Mpesiana, T. A. (2020). Covid-19: automatic detection from x-ray images utilizing transfer learning with convolutional neural networks. Physical and Engineering Sciences in Medicine, 1.
[25] Hemdan, E. E. D., Shouman, M. A., & Karar, M. E. (2020). Covidx-net: A framework of deep learning classifiers to diagnose covid-19 in x-ray images. arXiv preprint arXiv:2003.11055.
[26] Zhang, J., Xie, Y., Li, Y., Shen, C., & Xia, Y. (2020). Covid-19 screening on chest x-ray images using deep learning based anomaly detection. arXiv preprint arXiv:2003.12338.
[27] https://bluedot.global/ [last visited 07/04/2020]
[28] http://www.diseasedaily.org/about [last visited 07/04/2020]
[29] Abbas, A., Abdelsamea, M. M., & Gaber, M. M. (2020). Classification of COVID-19 in chest X-ray images using DeTraC deep convolutional neural network. arXiv preprint arXiv:2003.13815.
[30] Ruth Anita Shirley D, Ranjani K, Gokulalakshmi Arunachalam, Janeera D.A., "Distributed Gardening System Using Object Recognition and Visual Servoing" In International Conference on Inventive Communication and Computational Technologies [ICICCT 2020], Springer, India, 2020.