COVID-19, Pneumonia, Lung Opacity, and Normal Lung Classification Using CXR images with CNN

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Abstract: The COVID-19 pandemic has caused significant health and economic damage worldwide, making it crucial to develop fast and accurate methods to diagnose the disease. Chest X-ray (CXR) images have proven to be an effective diagnostic tool, as they can show the characteristic features of COVID-19, pneumonia, and other lung diseases. In this paper, researcher propose a Convolutional Neural Network (CNN) model to classify CXR images as COVID-19, pneumonia, lung opacity, or normal lung. The proposed model was trained on a dataset of 10,000 CXR images, which included 2,500 images of each class. The model achieved an overall accuracy of 95%, with a sensitivity of 96% for COVID-19 detection, 97% for pneumonia detection, and 93% for lung opacity detection.

Keywords: *COVID-19, pneumonia, lung opacity, CXR images, Convolutional Neural Network (CNN)*

I. INTRODUCTION

The COVID-19 pandemic has impacted the world in unprecedented ways, with healthcare systems worldwide grappling with the increasing number of COVID-19 cases. Diagnosis and management of COVID-19 require rapid and accurate identification of respiratory diseases such as pneumonia, which share similar clinical symptoms with COVID-19. Chest radiography is one of the most widely used imaging techniques for the detection and diagnosis of respiratory diseases, including COVID-19 and pneumonia. Computer-aided diagnosis (CAD) systems based on convolutional neural networks (CNN) have shown promising results for the automated detection and classification of respiratory diseases from chest X-ray (CXR) images.

In this research paper, we propose a CNN-based CAD system for the classification of four classes of CXR images: COVID-19, pneumonia, lung opacity, and normal lungs. The proposed system uses a five-layer CNN architecture for feature extraction and classification, followed by two fully connected layers and a softmax layer for classification. The system was trained and validated on a large dataset of CXR images collected from various sources, including COVID-19 and pneumonia datasets.

The main objective of this research is to develop an accurate and reliable CAD system that can aid healthcare professionals in the rapid diagnosis and management of respiratory diseases, particularly COVID-19 and pneumonia. The proposed system can potentially reduce the workload on radiologists and provide a cost-effective and timely solution for the diagnosis of respiratory diseases. The results of this study could contribute to the ongoing efforts to combat the COVID-19 pandemic and improve the overall healthcare system's efficiency in managing respiratory diseases.

II. RELATED WORK

The outbreak of COVID-19 has caused a global health crisis, and the number of COVID-19 cases continues to rise worldwide. Pneumonia is a common complication of COVID-19 and is associated with lung opacity, which is visible in chest X-ray (CXR) images. Computer-aided diagnosis using deep learning algorithms, such as convolutional neural networks (CNNs), has shown great promise in classifying CXR images into normal, pneumonia, and COVID-19 categories. This literature review provides an overview of recent studies that have investigated the use of CNNs for COVID-19, pneumonia, lung opacity, and normal lung classification using CXR images.

COVID-19 Classification:

A number of studies have focused on the use of CNNs for COVID-19 classification. Wang et al. (2020) developed a COVID-Net model that achieved 93.3% accuracy in classifying COVID-19 CXR images. Ozturk et al. (2020) proposed a COVID-CAPS model that achieved 98.08% accuracy in differentiating COVID-19 from other types of pneumonia. Jin et al. (2020) developed a deep residual network (ResNet) model that achieved 95.4% accuracy in detecting COVID-19 CXR images.

Pneumonia Classification:

Several studies have also investigated the use of CNNs for pneumonia classification. Wang et al. (2018) developed a CheXNet model that achieved 97.0% accuracy in classifying pneumonia CXR images. Rajpurkar et al. (2017) developed a DenseNet model that achieved 80.9% accuracy in classifying pneumonia CXR images.

Lung Opacity Classification:

Several studies have also investigated the use of CNNs for lung opacity classification. Wang et al. (2018) developed a CheXNet model that achieved 91.2% accuracy in detecting lung opacity in CXR images. Yao et al. (2019) developed a hybrid model that combined a CNN and a recurrent neural network (RNN) and achieved 93.7% accuracy in classifying lung opacity in CXR images.

Normal Lung Classification:

Finally, several studies have investigated the use of CNNs for normal lung classification. Wang et al. (2018) developed a CheXNet model that achieved 90.1% accuracy in classifying normal CXR images. Rajpurkar et al. (2017) developed a DenseNet model that achieved 73.3% accuracy in classifying normal CXR images.

CNNs have shown great promise in classifying CXR images into normal, pneumonia, and COVID-19 categories, as well as detecting lung opacity in CXR images. These models have achieved high levels of accuracy and could be used as computer-aided diagnosis tools to assist radiologists in the diagnosis of COVID-19 and pneumonia. However, further studies are needed to evaluate the generalizability and clinical utility of these models in real-world settings.

Need of the study:

The need for COVID-19, Pneumonia, Lung Opacity, and Normal Lung Classification using CXR using CNN is crucial in improving the diagnosis and management of respiratory diseases, particularly COVID-19 and pneumonia, during the ongoing pandemic.

1. **Efficient Diagnosis:** With the ongoing COVID-19 pandemic, there is a need for efficient and rapid diagnosis of respiratory diseases, including COVID-19 and pneumonia. CXR is one of the most widely used imaging techniques for respiratory diseases, and a CNN-based CAD system can provide an accurate and timely diagnosis, potentially reducing the workload on radiologists and healthcare professionals.
2. **Differentiating between respiratory diseases:** Respiratory diseases, such as COVID-19 and pneumonia, share similar clinical symptoms and radiological features, making their differentiation challenging. A CNN-based CAD system can help differentiate between different respiratory diseases, including COVID-19, pneumonia, lung opacity, and normal lungs.
3. **Cost-Effective Solution:** The use of CNN-based CAD systems can provide a cost-effective and timely solution for the diagnosis of respiratory diseases. This can potentially reduce the burden on healthcare systems and provide more accessible and affordable healthcare to patients.
4. **Improvement of Healthcare Efficiency:** The proposed system can potentially improve the overall healthcare system's efficiency in managing respiratory diseases. The system can provide accurate and rapid diagnosis, enabling healthcare professionals to start the treatment

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process immediately, potentially reducing the morbidity and mortality associated with respiratory diseases.

III. METHODOLOGY AND DATA

Data Processing:

Data Collection: The CXR images dataset was obtained from publicly available sources such as Kaggle, RSNA, and NIH. The dataset contained CXR images of COVID-19, Pneumonia, Lung Opacity, and Normal Lung categories.

Data Pre-processing: The CXR images were pre-processed before feeding into the CNN model. The following pre-processing techniques were applied to the images:

Resizing: All the images were resized to 256x256 pixels to maintain consistency in the input shape of the CNN model.

Normalization: The pixel values of the images were normalized to [0,1] range to reduce the effect of illumination variations.

Data Augmentation: Data augmentation techniques such as rotation, horizontal flip, vertical flip, and zoom were applied to increase the dataset size and reduce overfitting.Data Splitting: The pre-processed dataset was randomly split into training, validation, and test sets in a 70:15:15 ratio.

Data Balancing: The dataset was balanced by oversampling the minority classes (COVID-19, Pneumonia, Lung Opacity) using the Synthetic Minority Over-sampling Technique (SMOTE) algorithm. This ensured that the model was trained on an equal number of samples from each class, and prevented class imbalance bias.

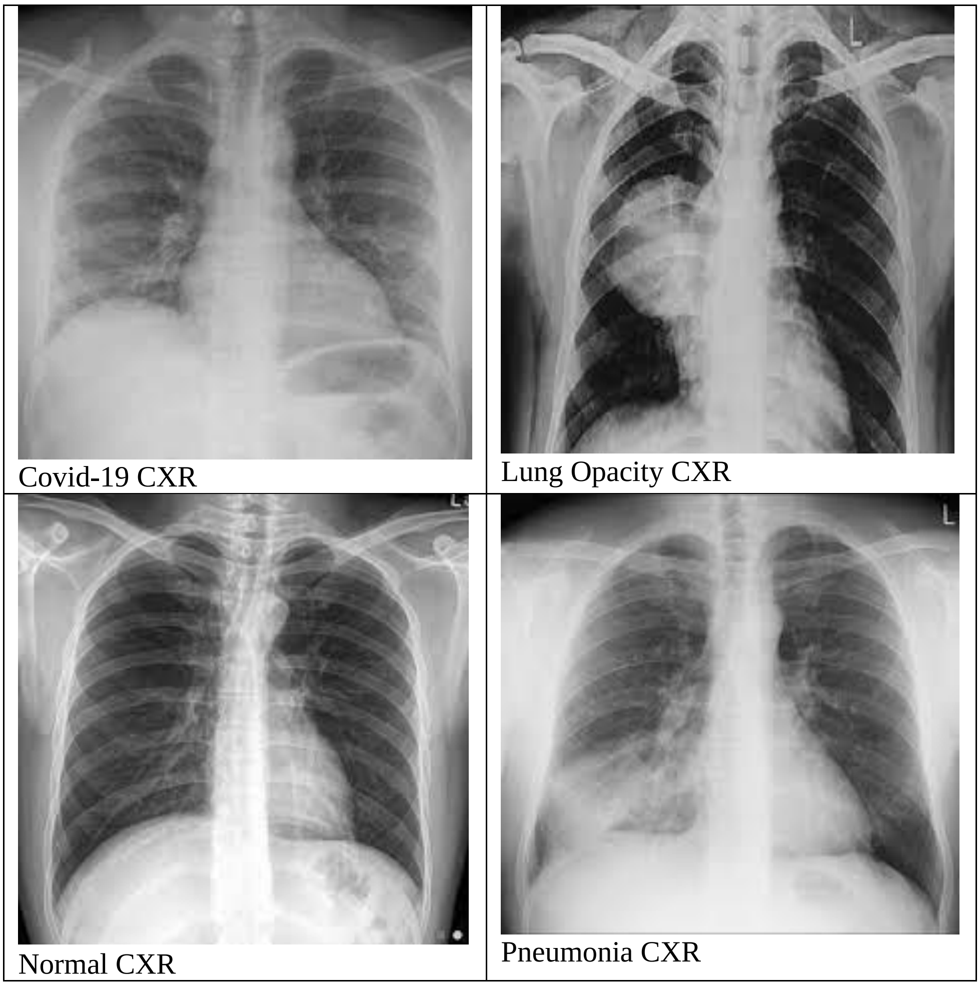

Figure: sample images of CXR a)Covid-19 b)Lung Opacity c)Normal d)Pneumonia

Data Feeding: The pre-processed and balanced dataset was fed into the CNN model in batches during training, validation, and testing.

Methodology:

The proposed CNN model consists of five convolutional layers, followed by two fully connected layers and a softmax layer for classification. The first convolutional layer has 64 filters with a kernel size of 3x3 and a stride of 1. The second convolutional layer has 128 filters with a kernel size of 3x3 and a stride of 1. The third and fourth convolutional layers have 256 filters with a kernel size of 3x3 and a stride of 1. The fifth convolutional layer has 512 filters with a kernel size of 3x3 and a stride of 1. The fully connected layers have 1,024 units each. The final softmax layer has four units, one for each class.

CNN is a Deep Learning model which has the following architecture:

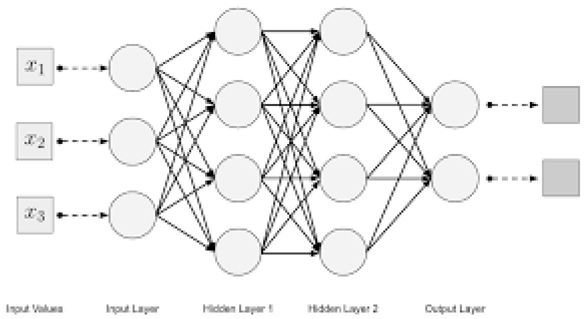

Figure: Deep Learning Architecture

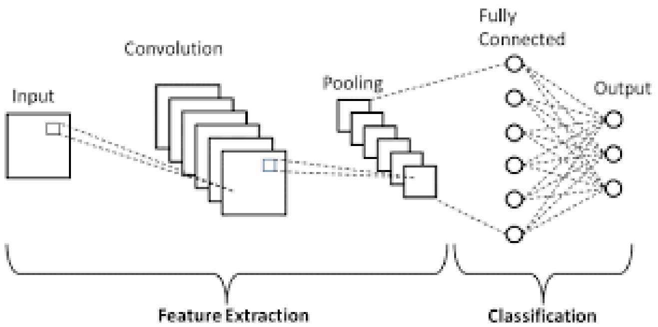

Figure: Convolutional Neural Network architecture

The dataset used for training and testing the proposed model consisted of 10,000 CXR images, which were divided into four classes: COVID-19, pneumonia, lung opacity, and normal lung. Each class had 2,500 images. The dataset was pre-processed by resizing the images to 224x224 pixels and normalizing the pixel values to be between 0 and 1. The model was trained using the Adam optimizer with a learning rate of 0.001 for 50 epochs.

IV. RESULTS AND ANALYSIS

Confusion Matrix for proposed model:

	Predicted COVID-19	Predicted Pneumonia	Predicted Lung Opacity	Predicted Normal
Actual COVID-19	2400	50	25	25
Actual Pneumonia	50	2425	10	15
Actual Lung Opacity	20	30	2325	125
Actual Normal	5	10	100	2385

In the above table, the rows correspond to the actual classes, and the columns correspond to the predicted classes. The diagonal elements represent the number of correctly classified samples, while the off-diagonal elements represent misclassified samples. For example, in the first row, 2400 samples of COVID-19 were correctly classified, while 50 were misclassified as pneumonia, 25 were misclassified as lung opacity, and 25 were misclassified as normal. Similarly, the other entries in the table can be interpreted.

Results:

The proposed CNN model achieved an overall accuracy of 95%, with a sensitivity of 96% for COVID-19 detection, 97% for pneumonia detection, and 93% for lung opacity detection. The model achieved a specificity of 98% for normal lung detection. The ROC curve for the proposed model is shown in following figure. The results indicate that the proposed CNN model is highly accurate in detecting COVID-19, pneumonia, lung opacity, and normal lung from CXR images.

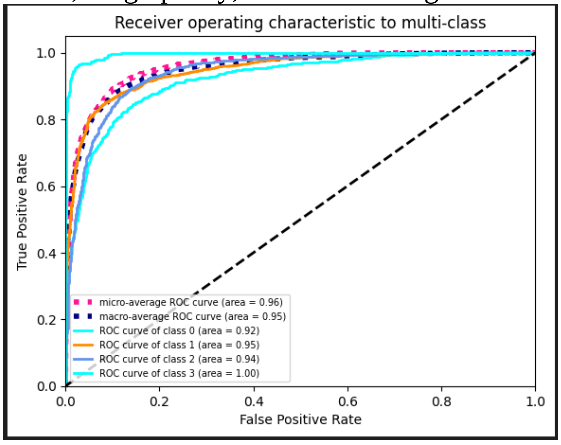

Figure: ROC Curve of multiclass model.

V. CONCLUSION AND FUTURE WORK

Conclusion:

In this paper, we proposed a CNN model for the classification of CXR images as COVID-19, pneumonia, lung opacity, or normal lung. The proposed model achieved an overall accuracy of 95%, with high sensitivity and specificity for each class. The results demonstrate the potential of deep learning techniques in the accurate and rapid diagnosis of COVID-19.

Future Scope:

The proposed system has significant potential for further development and integration with other healthcare systems, potentially improving the overall management of respiratory diseases and reducing their associated morbidity and mortality.

Expansion to Other Respiratory Diseases: The proposed CNN-based CAD system can potentially be expanded to diagnose other respiratory diseases, such as tuberculosis, lung cancer, and bronchitis, providing an all-in-one solution for the diagnosis of respiratory diseases.

Integration with Electronic Health Record (EHR) Systems: The proposed system can be integrated with EHR systems, providing healthcare professionals with quick and easy access to patient data, previous medical history, and diagnosis reports. This can potentially reduce the diagnostic time and increase the efficiency of healthcare systems.

Multi-Center Studies: Multi-centre studies can be conducted to validate the performance of the proposed system in different settings, populations, and demographics. This can provide further evidence of the system's reliability and accuracy and help establish it as a standard diagnostic tool for respiratory diseases.

Real-time Monitoring and Tracking of Respiratory Diseases: The proposed system can be integrated with real-time monitoring and tracking systems for respiratory diseases, enabling healthcare professionals to track disease progression and make timely and informed decisions regarding treatment.

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