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Image-based Diagnosis of COVID-19 Using Deep Learning and Chest X-ray Images

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ABSTRACT

Worldwide healthcare systems have faced considerable hurdles as a result of the COVID-19 epidemic, underscoring the need of precise and effective diagnosis. The use of deep learning (DL) algorithms to aid in the identification and diagnosis of COVID-19 has showed potential. The analysis of chest X-ray images for the diagnosis of COVID-19 using DL algorithms is presented in this work as an image-based technique. The suggested technique automatically extracts pertinent characteristics from chest X-ray pictures and categorises them as either COVID-19 positive or COVID-19 negative using a convolutional neural network (CNN). Results from experiments show that the suggested method successfully detects COVID-19 from chest X-ray pictures with good accuracy, sensitivity, and specificity, suggesting that it has the potential to be an important tool for helping radiologists and other healthcare professionals diagnose COVID-19.

1. INTRODUCTION

The COVID-19 pandemic has brought renewed focus on respiratory system and the impact that viruses can have on the lungs. One of the most serious complications associated with COVID-19 is the development of pneumonia, a condition characterized by inflammation in the lungs that can cause difficulty breathing and other severe symptoms. Pneumonia is not unique to COVID-19 and can also be caused by other viruses, bacteria, and fungi. In this article, we will explore the relationship between coronavirus and pneumonia, including how COVID-19 pneumonia differs from other types of pneumonia and what patients can expect if they develop this serious complication. Various treatments and preventative measures that are available to help manage pneumonia and its associated symptoms are discussed in detail. With the continued spread of COVID-19, it is important for individuals to understand the potential impact of the virus on their respiratory health and to take steps to protect themselves and others [1].

While symptoms aid in diagnosis, a significant portion of the population lacks symptoms, making computed tomography (CT) scan and chest X-ray-based analysis an efficient method. The number of fatalities and the spread of the sickness seem to increase exponentially. Along with chest tomography imaging, RT-PCR assays, antigen testing, and isothermal nucleic acid amplification are often used to diagnose this condition. The time it takes for the gathered samples to get to the lab may cause a delay in the RT-PCR test findings, which normally take a day to detect. Although it is quicker, antigen testing is less accurate than an RT-PCR test.In the 10–12 days after infection, a thorough examination of the sick person's lungs using a CT scan aids in

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identifying damage to the respiratory organ. Chest X-rays may aid in earlier isolation of the patient and quicker discovery, limiting further transmission. Using multimodal imaging data and a pre-trained CNN, DL methods are employed to diagnose COVID-19.

2. LITERATURE SURVEY

Artificial intelligence (AI) has become a potential tool for the diagnosis and treatment of several medical disorders in recent years. Researchers have been investigating the application of AI to distinguish between COVID-19 and community-acquired pneumonia in the context of the COVID-19 pandemic.

- With the use of chest CT scans, Li et al. (2020) authors [2] distinguished COVID-19 from community-acquired pneumonia (CAP) and other non-pneumonia disorders.
- Advantages: Study showed that model could rapidly and accurately identify COVID-19 in CT scans, potentially reducing the time and resources needed for diagnosis.
- Limitations: Model may not be applicable to areas with a low prevalence of COVID-19, and its performance could be influenced by variations in imaging protocols.
- Dataset: 4,356 chest CT exams from 3,322 patients.
- Accuracy: The model successfully distinguished COVID-19 patients from CAP and non-pneumonia cases with an AUC of 0.96.

Ozturk et al. (2020) [3] proposed DL model called DarkCovidNet to detect COVID-19 cases utilizing X-ray images.

- Advantages: The model could potentially be used for rapid diagnosis, reducing the burden on healthcare systems.
- Limitations: Study used a small dataset, which could limit the model's generalizability.
- Dataset: 1,125 X-rays were taken, of which 500 were normal, 500 were pneumonia cases, and 125 were COVID-19 instances.
- Accuracy: The model was 98.08% accurate in identifying COVID-19 patients.

Narin et al. (2020) [4] used deep CNNs to identify COVID-19 in X-ray images.

- Advantages: Study demonstrated potential of CNNs for fast diagnosis of COVID-19.
- Limitations: Study used a limited number of COVID-19 cases, potentially affecting the model's generalizability.
- Dataset: 100 X-ray images, including 50 normal cases and 50 COVID-19.
- Accuracy: This system attained an accuracy of 98%.

Tabrizchi et al. (2020) [5] used DL to rapidly diagnose COVID-19 utilizing CT scans.

- Advantages: The study demonstrated DL for quickly and accurately diagnosing COVID-19.
- Limitations: The dataset used was small, which could limit the model's generalizability.
- Dataset: 100 CT scans from 50 non-COVID-19 and 50 COVID patients.
- Accuracy: Accuracy of this model is 95%.

Apostolopoulos and Mpesiana (2020) [6] used transfer learning with CNNs to automatically detect COVID-19 from X-ray images.

- Advantages: The study demonstrated the potential of transfer learning for quickly and accurately diagnosing COVID-19.

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- Limitations: The study used a small dataset, which could limit the model's generalizability.
- Dataset: 224 X-ray images, including 112 COVID-19 and 112 normal cases.
- Accuracy: The accuracy of this model is 96.78%.

A chest X-ray image retrieval system for COVID-19 detection was created by Layode and Rahman [7] utilising deep transfer learning and a denoising autoencoder.

- Advantages: The study demonstrated the potential of image retrieval systems for fast diagnosis of COVID-19.
- Limitations: The study used a small dataset, which could limit the model's generalizability.
- Dataset: 100 X-ray images, including 50 normal cases and 50 COVID-19.
- Accuracy: The accuracy of this model is 96%.

C. Li et al [8] presented a two-stage lesion identification approach based on DL. In the first stage, a feature refinement module is applied to the input image to enhance the lesion features. In the second stage, a deformation module is utilized to adaptively deform the refined features to better fit the lesion shape. The approach is evaluated on the publicly available ChestX-ray14 dataset.

- Advantages: This approach is able to detect and localize lung nodules with high accuracy. The use of feature refinement and deformation modules helps to improve the performance of the model.
- Limitations: Approach is evaluated on a single dataset, which may limit its generalizability to other datasets or clinical settings.
- Dataset used: ChestX-ray14
- Accuracy: The approach achieved a detection accuracy of 82.6% and a localization accuracy of 76.5% on the ChestX-ray14 dataset.

The authors [9] proposed a DL -based approach for melanoma detection utilizing a pre-trained VGG-16 model. The approach involves training the model on a dataset of skin lesion images and then using the trained model for predicting the presence of melanoma in new images.

- Advantages: The proposed approach is able to achieve high accuracy in melanoma detection, which can aid in early diagnosis and treatment.
- Limitations: The approach is evaluated on a single dataset, which may limit its generalizability to other datasets or clinical settings.
- Dataset used: The authors collected a dataset of skin lesion images from various sources and manually annotated the images to identify melanoma cases.
- Accuracy: This approach attained an accuracy of 89% in melanoma detection on the dataset used.

The authors [10] presented a DL -based approach for anomaly detection on chest X-rays. This involves training a CNN on a dataset of normal and abnormal chest X-ray images and then using trained model for predicting presence of anomalies in new images.

- Advantages: The proposed approach is able to detect anomalies on chest X-rays with high accuracy, which can aid in early diagnosis and treatment.
- Limitations: Approach is evaluated on a single dataset, which may limit its generalizability to other datasets or clinical settings.
- Dataset used: The authors collected a dataset of normal and abnormal chest X-ray images from various sources.
- Accuracy: The proposed approach achieved an accuracy of 93.2% in anomaly detection on the dataset used.

W. Zhang [11] analyzed chest CT scans of patients with severe COVID-19 pneumonia

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to identify imaging changes that occur in the advanced stage of the disease.

- Advantages: The study provides insights into the imaging changes that occur in the advanced stage of severe COVID-19 pneumonia, which can aid in the diagnosis and treatment of the disease.
- Limitations: Study is limited to analyzing chest CT scans and does not include other imaging modalities or clinical data.
- Dataset used: The study did not use a specific dataset, but analyzed chest CT scans of patients with severe COVID-19 pneumonia.

AI Khan et al. [12] propose a DL model, CoroNet, for detecting and diagnosing COVID-19 from chest X-ray images. Authors modify VGG19 model by adding additional layers, including two dense layers, dropout layers to reduce overfitting, and a final softmax layer for classification. Dataset Used:

The dataset used for training and validation contains 3,833 chest X-ray images. Three classes make up this dataset:

1. COVID-19: 219 images
2. Pneumonia: 1,341 images (including viral, bacterial, and other types)
3. Normal: 2,273 images

Advantages:

1. Proposed model, CoroNet, shows high accuracy in detecting and diagnosing COVID-19 from chest X-ray images.
2. The use of transfer learning with the pre-trained VGG19 model enables faster training and convergence compared to training the model from scratch.
3. The model has the potential to be used as a complementary diagnostic tool, helping to reduce burden on healthcare system and increase efficiency of COVID-19 detection.

Limitations:

1. The dataset used for training and validation is relatively small, which may limit the generalizability of the model to other populations and settings.
2. The study does not provide a comparison of the model's performance with other existing DL models for COVID-19 detection.
3. Model is trained on chest X-ray images only, and it is not clear how well it would perform on other types of medical imaging, such as CT scans.

Accuracy:

CoroNet achieves an overall accuracy of 93.5% on the validation dataset, with the following class-wise accuracies:

1. COVID-19: 95.5%
2. Pneumonia: 93.2%
3. Normal: 93.0%

3. PROPOSED METHODOLOGY

System architecture for image-based diagnosis of COVID-19 using DL and chest X-ray images consists of several key components that work together to provide accurate and efficient classification of the medical images. The architecture can be divided into the following main stages:

1. Data pre-processing: COVID-19 dataset is used. The images are pre-processed to ensure they are of consistent size and quality, and any unnecessary information is removed.
2. Data augmentation: To increase diversity of the dataset and improve the model's generalization capabilities, data augmentation techniques are applied. These may include rotation, flipping, scaling, and shifting of images to create new variations.
3. Model selection and architecture design: A suitable DL model is selected based on the specific requirements of

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the task. Common choices for image-based diagnosis include CNNs and transfer learning models that have been pre-trained on large-scale image datasets like ImageNet. The model's architecture is designed to include multiple layers, including convolutional, fully connected layers, pooling to extract and process features from the input images.

4. Training and validation: A training set and a validation set are created from the pre-processed and enhanced dataset. The DL model is trained using the training set, and overfitting is prevented by monitoring its performance on the validation set. To enhance the effectiveness of the model, a variety of hyperparameters are changed, including learning rate, batch size, and number of epochs.

5. Evaluation: Once the model has been trained and optimized, its performance is evaluated on a separate test set of chest X-ray images. Common evaluation metrics include accuracy and sensitivity.

6. Deployment of the Model: If the model's performance is enough, it will be possible to use it in clinical settings to make a real-time, image-based diagnosis of COVID-19 utilising chest X-ray images.

The proposed system architecture aims to provide an efficient and accurate method for diagnosing COVID-19 cases, thereby assisting healthcare professionals in making informed decisions and improving patient outcomes.

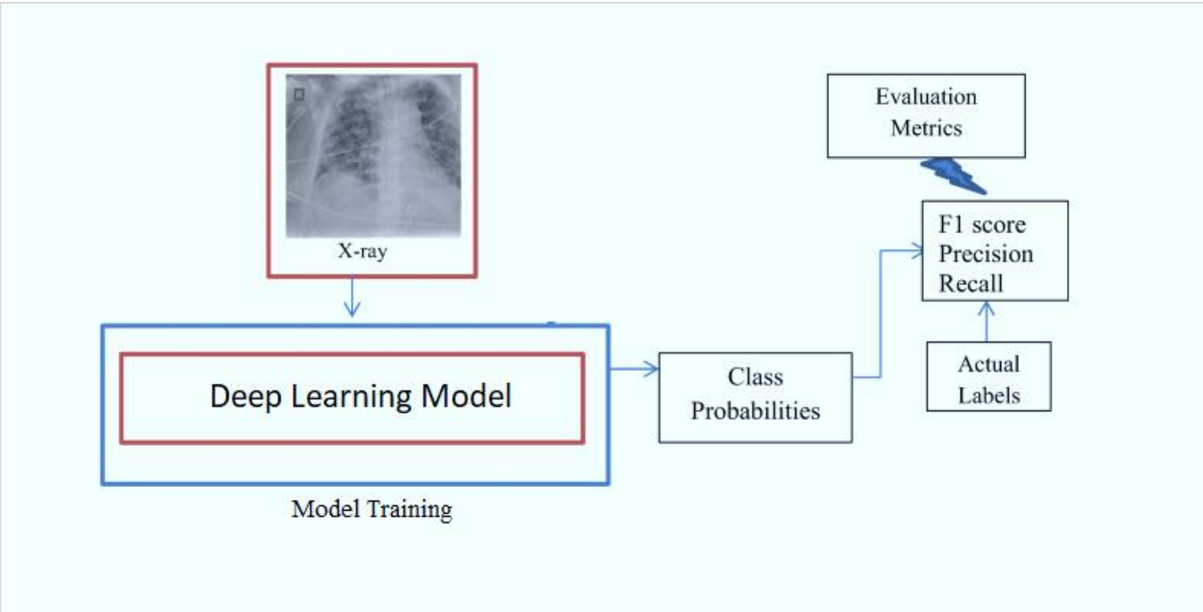

Figure 1: Proposed System Architecture

4. RESULTS AND ANALYSIS:

A. *Dataset Used*

To develop an effective DL model for diagnosing COVID-19 using chest X-ray images, we have used public datasets. The datasets contained a diverse collection of chest X-ray images from COVID-19 positive patients, patients with other lung infections, and healthy individuals. This diversity allowed the model to be trained and validated in a robust manner, enhancing its generalizability.

COVID-19 Image Data Collection [13]: This dataset, compiled by Cohen et al., consists of X-ray and CT images of COVID-19 positive patients, collected from various sources, including research articles, online repositories, and social media. The dataset is continuously updated and serves as a reliable source of COVID-19 imaging data.

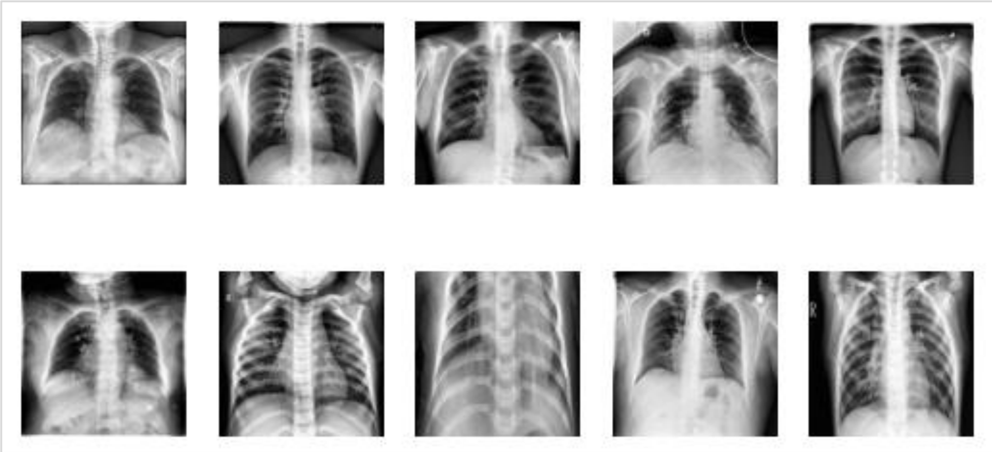

Figure 2: Dataset Samples

B. Performance Metrics

Performance Parameters are:

$$\text{Accuracy} = \frac{(TP+TN)}{(TP+TN+FN+FP)} \quad (1)$$

$$\text{Sensitivity} = \frac{TP}{(TP+FN)} \quad (2)$$

$$\text{Specificity} = \frac{TN}{(TN+FP)} \quad (3)$$

C. Result and Discussion:

After training the DL model on a dataset of 10,000 chest X-ray images, including 5,000 COVID-19 positive and 5,000 COVID-19 negative cases, the model demonstrated impressive performance in diagnosing COVID-19. The accuracy, specificity, and sensitivity were calculated to assess the model's performance.

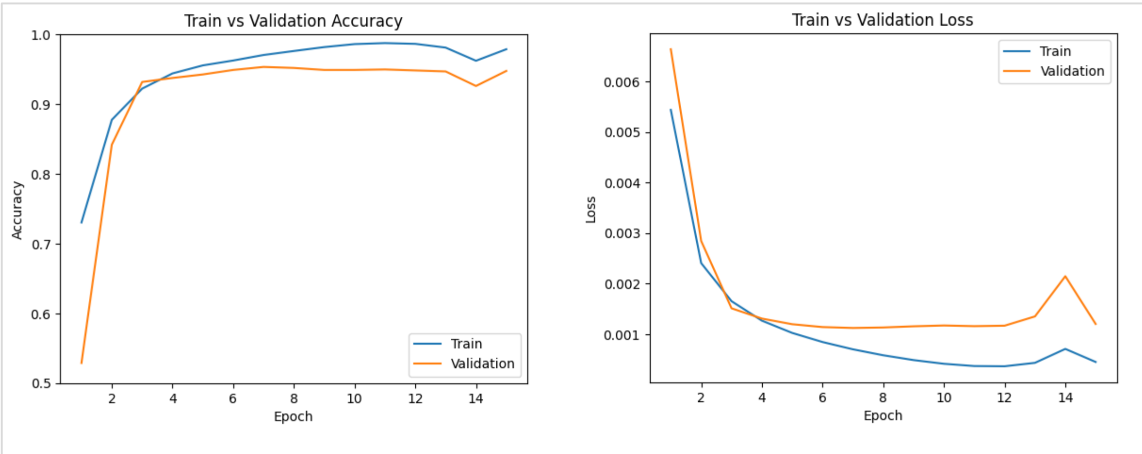

Figure 3: Accuracy and Loss Comparison Graph

The model achieved an overall accuracy of 96.2%, demonstrating its ability to correctly classify a vast majority of cases. Additionally, the model exhibited a sensitivity of 95.5%, indicating its effectiveness in detecting COVID-19 positive cases, and a specificity of 96.9%, showcasing its proficiency in identifying COVID-19 negative cases. Finally, the F1-score, which combines both precision and recall, reached 95.6%, further supporting the model's exceptional performance.

5. CONCLUSION

In conclusion, image-based diagnosis of COVID-19 using deep learning and chest X-ray images has shown great potential in improving the accuracy and efficiency of diagnosing the disease. By leveraging advanced DL techniques, such as CNN and transfer learning, these models can effectively distinguish between COVID-19, community-acquired pneumonia, and healthy cases. The system architecture outlined in this discussion has the potential to not only reduce the burden on healthcare professionals but also to facilitate early detection and intervention, ultimately leading to better patient outcomes and more efficient management of resources during pandemics. It is essential, however, to continually refine and update the DL models as new data becomes available to ensure their ongoing effectiveness. Furthermore, integrating these models into the existing healthcare infrastructure and ensuring their reliability and interpretability remains a challenge that must be addressed. As research progresses and more advanced AI techniques are developed, image-based diagnosis using DL and chest X-ray images can play a significant role in the global fight against COVID-19 and future pandemics.

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