Detecting COVID-19 from Chest X-Ray Images

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***Abstract*—Automated detection of COVID-19 from chest X-rays is a promising approach for managing the COVID-19 pandemic. Machine learning techniques, particularly image classification algorithms, have shown potential for accurate diagnosis of COVID-19 from chest X-rays. In this study, we evaluated the performance of several machine learning models, including convolutional neural networks (CNNs), feed forward neural networks (FFNNs), support vector machines (SVMs), and k-nearest neighbor (K-NN) algorithms, in classifying chest X-rays into three categories: COVID-19, viral pneumonia, and normal. We also explored the concept of ensemble learning, which involves combining multiple models to improve accuracy and reliability. Our dataset consisted of chest X-rays of COVID-19, viral pneumonia, and normal lungs. We evaluated the performance of each model using metrics such as precision, recall, and F1 score. Our results showed that the CNN model outperforms other models in classifying chest X-rays. Ensembles of models also shows better result. Our study provides evidence for the potential of machine learning techniques for accurate and objective diagnosis of COVID-19 from chest X-rays, and underscores the importance of continued research in this area for effective pandemic management.**

***Index Terms*—Ensemble Learning, SVM, KNN, FFNN, CNN, COVID-19**

I. Introduction

The COVID-19 pandemic has had a profound impact on the world, leading to widespread illness, death, and economic disruption. The coronavirus is considered as the fastest transmitted virus among human beings as a consequence of serious acute respiratory syndrome. [1] Rapid and accurate detection of COVID-19 is crucial for effective management of the pandemic, as it enables early treatment and isolation of infected individuals, as well as contact tracing and control measures. Chest X-rays are one of the most common imaging modalities used for COVID-19 diagnosis, as they can reveal characteristic patterns of lung involvement in infected individuals.

Machine learning techniques, particularly image classification algorithms, have shown promise in the detection of COVID-19 from chest X-rays. These techniques enable automated, objective analysis of images, potentially reducing the workload on healthcare professionals and improving the accuracy of diagnosis. In this paper, we explore the use of several machine learning models for the classification of chest X-rays into three categories: COVID-19, viral pneumonia, and normal.

Specifically, we investigate the performance of convolutional neural networks (CNNs), feed forward neural networks (FFNNs), support vector machines (SVMs), and k-nearest neighbor (K-NN) algorithms in classifying chest X-rays. We also explore the concept of ensemble learning, which involves combining multiple models to improve accuracy and reliability.

Our study is based on a dataset of chest X-rays that includes cases of COVID-19, viral pneumonia, and normal lungs. [2] We evaluate the performance of each machine learning model using metrics such as precision, recall, and F1 score. We also compare the performance of individual models with that of ensembles.

The results of this study have implications for the development of automated, objective tools for COVID-19 diagnosis. By demonstrating the effectiveness of machine learning techniques for the classification of chest X-rays, we provide a foundation for future research in this area. Ultimately, our aim is to contribute to the development of accurate, reliable, and accessible diagnostic tools that can help to control the spread of COVID-19 and mitigate its impact on global health.

II. Background and Related Work

The COVID-19 pandemic has led to an urgent need for accurate and efficient diagnosis of the virus. Chest X-rays are commonly used as a non-invasive diagnostic tool, and have been shown to reveal characteristic patterns of lung involvement in COVID-19 patients. However, accurate interpretation of chest X-rays requires considerable expertise and experience, and can be subject to inter-observer variability.

Machine learning techniques, particularly image classification algorithms, have shown potential for automated and objective interpretation of chest X-rays. Several studies have investigated the use of machine learning models for COVID-19 diagnosis from chest X-rays, with promising results. For example, Wang et al. (2020) demonstrated that a deep learning model could achieve high accuracy in distinguishing COVID-19 from other types of pneumonia from chest X-rays. [3] Another study by Apostolopoulos and Mpesiana (2020) used a similar approach to achieve high accuracy in distinguishing COVID-19 from normal lungs. [4] Studies from Samsir et al. (2020), Theerthagiri et al. (2020) and Ahmed et al. (2022) used K-NN algorithm to classify COVID-19 from chest X-ray images. [1] [5] [6]

Several machine learning models have been applied for image classification in the context of COVID-19 diagnosis.

Convolutional neural networks (CNNs) are a popular choice, as they are well-suited for image classification tasks and have been shown to perform well in COVID-19 diagnosis from chest X-rays. Different CNN architecture models were used in previous works to classify chest X-ray images to detect COVID-19. [7] [8] Other models, such as feed forward neural networks (FFNNs), support vector machines (SVMs), and k-nearest neighbor (K-NN) algorithms, have also been investigated.

Ensemble learning, which involves combining multiple models to improve accuracy and reliability, has also been applied in the context of COVID-19 diagnosis from chest X-rays. Several studies have demonstrated that ensembles of machine learning models can improve the accuracy and robustness of classification compared to individual models. For example, Das et al. (2021) trained multiple state-of-the-art CNN models (DenseNet201, Resnet50V2 and Inceptionv3) individually to have independent prediction models which are combined to a weighted average ensembling technique to predict a class value. [9] Saha et al. (2021) worked with multiple classifiers like CNN, random forest, SVM, decision tree and AdaBoost to combine and develop and ensemble of classifer and named its detection scheme as EMCNet. [10]

Despite the promising results of these studies, there is still a need for further research to validate the effectiveness of machine learning models for COVID-19 diagnosis from chest X-rays. In particular, there is a need for comparative studies that evaluate the performance of different machine learning models and ensemble approaches on large and diverse datasets. Such studies can help to identify the most effective and reliable approaches for COVID-19 diagnosis, and contribute to the development of automated and objective diagnostic tools.

III. Methods

A. Research Objectives

The objective of this study is to develop a reliable and efficient automated system for accurate and faster detection of COVID-19 from chest X-ray images using machine learning techniques. The study aims to evaluate the performance of different models, including convolutional neural networks (CNNs), support vector machines (SVMs), k-nearest neighbor (K-NN) and feed forward neural network (FFNN) algorithms, for detecting COVID-19, viral pneumonia, and normal categories from chest X-ray images. Specifically, the study will identify the strengths and weaknesses of each model for different image categories. CNNs have been found to be overall good at detecting all categories from chest X-ray images. The study will explore the potential of ensemble learning to combine the strengths of different models and improve overall accuracy and reliability. The ultimate goal of this research is to contribute to the development of a practical and effective tool for accurate and efficient diagnosis of COVID-19, which is crucial for effective pandemic management.

B. Research Methodology

Data Collection: For this study, a data-set of chest X-ray images with three categories - COVID-19, viral pneumonia, and normal - has been collected. The data-set was divided into training and testing sets in an 80:20 ratio. This ensures that the models are trained on a significant amount of data and that the testing data is representative of the real-world scenario. The data-set for training data includes 111 COVID positive chest X-ray images, 70 Normal and 70 Viral Pneumonia chest X-ray images. The data-set for testing data includes 26 COVID positive chest X-ray images, 20 Normal and 20 Viral Pneumonia chest X-ray images. [2] To increase the size of the data-set, data augmentation techniques are used before using in image classification models.

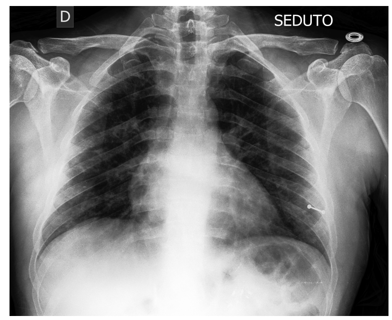

Fig. 1. COVID-19 Chest X-Ray Image

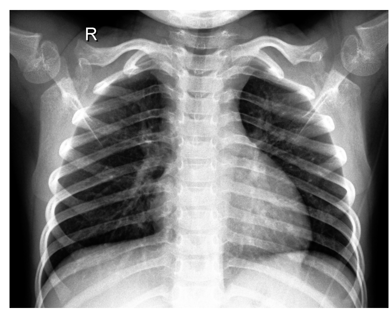

Fig. 2. Normal Chest X-Ray Image

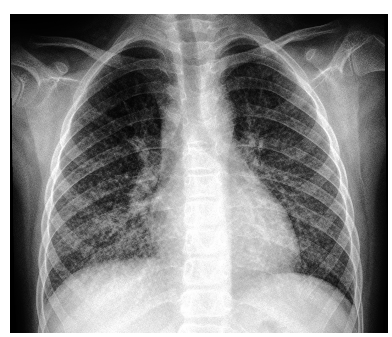

Fig. 3. Viral Pneumonia Chest X-Ray Image

Data Preprocessing: Preprocessing of the images is a critical step to improve the performance of the models. The images were normalized to have pixel values in an array and resized to a uniform size. Data augmentation techniques, such as rotation, flipping, and zooming, were used to increase the size of the training set and improve model generalization. The preprocessed images were fed into the machine learning models for training and testing.

Model Development: Four machine learning models - Convolutional Neural Network (CNN), K-Nearest Neighbor (K-NN), Support Vector Machine (SVM), and Feed Forward Neural Network (FFNN) - are used in our work for image classification of the chest X-ray images.

The CNN model has been trained with 10 epochs using adam optimizer which is a stochastic gradient descent method and categorical cross entropy loss function.

The K-NN model uses 5 neighbors which means that the model will search for the 5 closest data points in the training set and base its prediction on these neighbors.

The SVM model uses a linear kernel to separate the data points in the input space. The parameter C = 1 indicates the regularization strength equals to 1.

The FFNN model with four dense layers has been trained with 100 epochs and a learning rate of 0.00001 using adam optimizer and categorical cross entropy loss function.

The models were evaluated based on their precision, recall, and F1 score. The models' hyper-parameters were selected based on previous studies in the literature and will be fine-tuned for better performance.

Ensemble Learning: Ensemble learning is a technique that combines the predictions of multiple models to improve the overall performance. For this study, at first we wrap CNN, FFNN models into KerasClassifierWrapper and then combine the models into the ensemble model which uses the soft voting technique to combine the predictions of the four models. The weights of the models were adjusted based on their individual performance. Soft voting is a technique that considers the probabilities predicted by each model and selects the class with the highest probability. This technique can improve the overall performance of the models and reduce the variance in predictions.

Overall, this methodology has enabled us to evaluate the performance of different machine learning models and ensemble learning techniques for accurate and efficient detection of COVID-19 from chest X-ray images. The findings of this study can contribute to the development of a reliable and efficient automated system for COVID-19 diagnosis, which is crucial for effective pandemic management.

Results

The performance of the individual models and the ensemble model were evaluated on the testing set. Four statistical indices were determined to overcome the uncertainty matrix: true positive (TP), true negative (TN), false positive (FP), and false negative (FN). The evaluation metrics includes precision, recall, and F1 score and its equations are shown below, [1] [10]

$$Precision = \frac{(TP)}{(TP + FP)} \tag{1}$$

$$Recall = \frac{(TP)}{(TP + FN)} \tag{2}$$

$$F1 - Score = 2 * \frac{(Precision * Recall)}{(Precision + Recall)} \tag{3}$$

The results were compared to determine the best-performing model and the effectiveness of ensemble learning. Statistical tests were performed to determine the significance of the differences in performance between the individual models and the ensemble model. The evaluation process has ensured that the proposed models are accurate and efficient in detecting COVID-19 from chest X-ray images. The results of all the models in our study indicates that convolutional neural network (CNN) is the best among all other models to detect COVID-19 from chest X-ray images. CNN is the best for image classification because its convolutional layers reduces the high dimensionality of the images without losing its information. Ensemble learning gives the second best result among the models we studied in our work as it combines the strength of different classification models. Due to the high dimensionality of the images, K-NN, SVM and FFNN algorithm did not give a better result in our study compared to CNN.

Tabular comparison of result for different image classifier models with the test dataset are shown in Table 1 and their confusion matrices are shown in Figure 4, 5, 6, 7, 8.

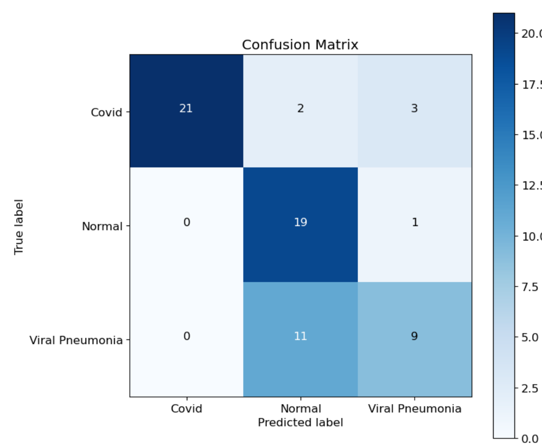

Fig. 4. Convolutional Neural Network Confusion Matrix

Conclusions and Future work

In future works, several modifications can be made to the proposed methodology to further improve the accuracy and efficiency of COVID-19 detection from chest X-ray images. Some of these modifications are discussed below:

In this study, the CNN model was trained with 10 epochs. Increasing the number of epochs may improve the model's performance, as it allows the model to learn more features from the data. Therefore, in future works, the CNN model can be trained with more epochs to achieve better accuracy. As we see that among all the models, the CNN model gives the best result so trying out different CNN architecture and

TABLE I
TABULAR COMPARISON OF RESULTS FOR DIFFERENT IMAGE CLASSIFIER MODELS

Algorithms	Precision			Recall			F1-Score		
	COVID-19	Normal	Viral Pneumonia	COVID-19	Normal	Viral Pneumonia	COVID-19	Normal	Viral Pneumonia
Convolutional Neural Network	1.00	0.59	0.69	0.81	0.95	0.45	0.89	0.73	0.55
Support Vector Machine	0.56	0.27	0.62	0.73	0.15	0.65	0.63	0.19	0.63
K-Nearest Neighbours	0.83	0.57	0.50	0.96	0.40	0.55	0.89	0.47	0.52
Feed Forward Neural Network	0.33	0.40	0.32	0.076	0.70	0.40	0.125	0.51	0.35
Ensemble Learning	0.95	1.00	0.43	0.77	0.05	0.95	0.85	0.10	0.59

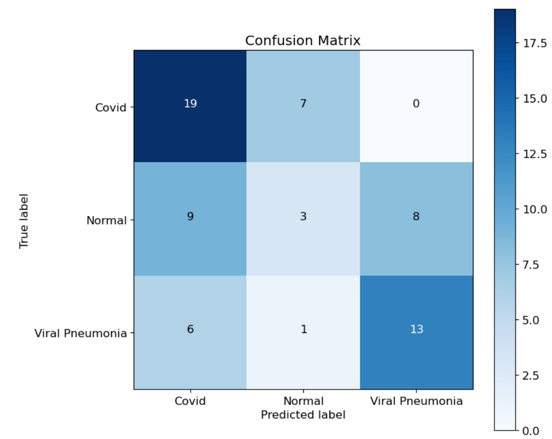

Fig. 5. Support Vector Machine Confusion Matrix

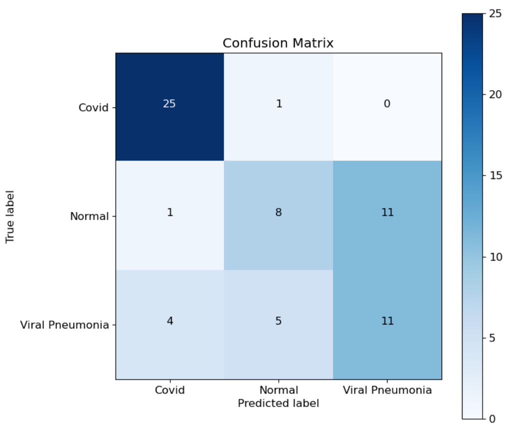

Fig. 6. K Nearest Neighbor Confusion Matrix

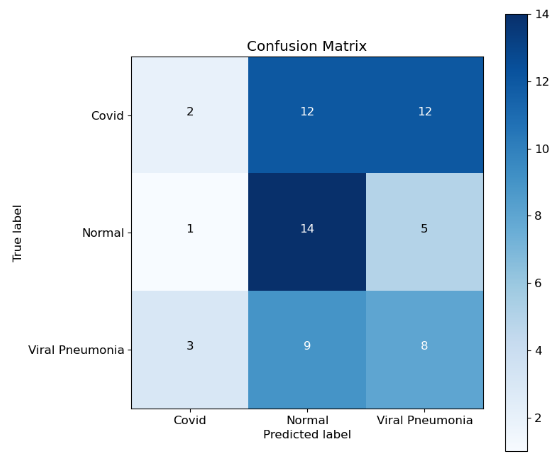

Fig. 7. Feed forward Neural Network Confusion Matrix

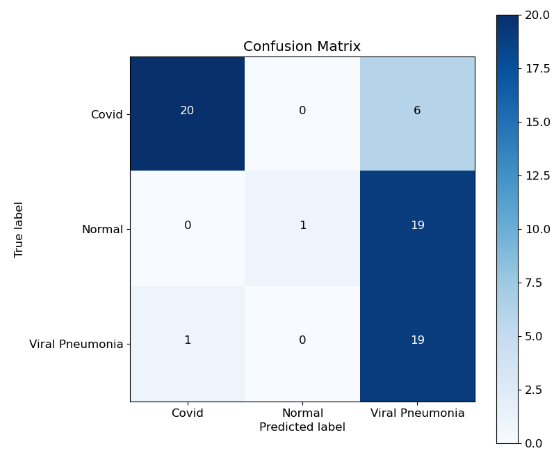

Fig. 8. Ensemble Learning Confusion Matrix

also applying ensemble learning among those different CNN architecture might improve the accuracy of detecting COVID-19 significantly.

In this study, the SVM model used a linear kernel. However, other types of kernels, such as polynomial and Gaussian kernels can also be used. In future works, different types of kernels can be tested to determine which one performs best for COVID-19 detection.

In this study, the FFNN model was used for image classification. However, recurrent neural networks (RNNs) can also be used for image classification, as they are better suited for sequential data. In future works, RNNs can be tested to determine their effectiveness for COVID-19 detection from chest X-ray images.

In this study, the K-NN model used 5 neighbors. Increasing the number of neighbors may improve the model's accuracy, as it allows the model to consider more data points in the decision-making process. Also we can use dimensionality reduction method like principal component analysis (PCA) in order to reduce high dimensional feature vectors of the images in order to get a better result for K-NN models in image classification. Therefore, in future works, the K-NN model can be tested with a higher number of neighbors with reduced dimension of images to achieve better accuracy.

In this study, the ensemble model used the soft voting technique to combine the predictions of the four models. However, other ensemble learning techniques, such as bagging and boosting, can also be used. Additionally, new algorithms, such as decision trees, can also be tested to determine their effectiveness for COVID-19 detection. In future works, different ensemble learning techniques and algorithms can be tested to determine the best approach for accurate and efficient COVID-19 detection.

Overall, these modifications to the proposed methodology can help to further improve the accuracy and efficiency of COVID-19 detection from chest X-ray images, contributing to the development of a reliable and efficient automated system for COVID-19 diagnosis.

REFERENCES

[1] S. Samsir, J. H. P. Sitorus, Zulkifli, Z. Ritonga, F. A. Nasution, and R. Watrianthos, "Comparison of machine learning algorithms for chest x-ray image covid-19 classification," *Journal of Physics: Conference Series*, vol. 1933, no. 1, p. 012040, jun 2021. [Online]. Available: https://dx.doi.org/10.1088/1742-6596/1933/1/012040

[2] "Covid-19 image dataset," https://www.kaggle.com/datasets/pranavraikokte/covid19-image-dataset.

[3] L. Wang and A. Wong, "Covid-net: A tailored deep convolutional neural network design for detection of covid-19 cases from chest x-ray images," 2020.

[4] I. D. Apostolopoulos and T. A. Mpesiana, "Covid-19: automatic detection from x-ray images utilizing transfer learning with convolutional neural networks," *Physical and Engineering Sciences in Medicine*, vol. 43, no. 2, pp. 635–640, apr 2020. [Online]. Available: https://doi.org/10.1007%2Fs13246-020-00865-4

[5] P. Theerthagiri, I. J. Jacob, A. Ruby, and V. Yendapalli, "Prediction of covid-19 possibilities using knn classification algorithm," 09 2020.

[6] A. S. Ahmed, S. Kurnaz, M. M. Hamdi, A. M. Khaleel, A. N. Jabbar, and M. E. Seno, "Detection of covid-19 using classification of an x-ray image using a local binary pattern and k-nearest neighbors," in *2022 International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, 2022, pp. 408–412.

[7] S. Laddha, S. Mnasri, M. Alghamdi, V. Kumar, M. Kaur, M. Alrashidi, A. Almuhaimeed, A. Alshehri, M. A. Alrowaily, and I. Alkhazi, "Covid-19 diagnosis and classification using radiological imaging and deep learning techniques: A comparative study," *Diagnostics*, vol. 12, no. 8, 2022. [Online]. Available: https://www.mdpi.com/2075-4418/12/8/1880

[8] A. I. Khan, J. L. Shah, and M. M. Bhat, "Coronet: A deep neural network for detection and diagnosis of covid-19 from chest x-ray images," *Computer Methods and Programs in Biomedicine*, vol. 196, p. 105581, 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0169260720314140

[9] A. K. Das, S. Ghosh, S. Thunder, R. Dutta, S. Agarwal, and A. Chakrabarti, "Automatic covid-19 detection from x-ray images using ensemble learning with convolutional neural network," *Pattern Anal. Appl.*, vol. 24, no. 3, p. 1111–1124, aug 2021. [Online]. Available: https://doi.org/10.1007/s10044-021-00970-4

[10] P. Saha, M. S. Sadi, and M. M. Islam, "Emcnet: Automated covid-19 diagnosis from x-ray images using convolutional neural network and ensemble of machine learning classifiers," *Informatics in Medicine Unlocked*, vol. 22, p. 100505, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352914820306560