The abnormalities can only be explained by expert radiologists. With the huge number of suspected cases and the limited number of available radiologists, automatic methodologies for the recognition of these precise abnormalities can aid in early diagnosis with high accuracy. The studies in Artificial Intelligence (AI) and machine learning, especially Deep Learning (DL), achieved high performance in the diagnosis of medical images. Therefore, DL techniques are robust tools for such issues.

Deep learning (DL) has been successfully used to predict COVID-19 from Chest images. Unlike the traditional machine learning techniques DL can be used to predict disease from raw images without feature extraction required. The role of deep learning is to learn the features using a trained model with a huge amount of data to improve the classification's accuracy which reduces the burden on physicians and decreases the effect of doctors' shortages of the struggle against the disease. Convolutional neural network (CNN) is the type of DL model intended for image analysis tasks and has already been utilized in many medical problems such as segmentation and classification[12].

Many high-performing pre-trained CNN structures have been provided in the literature to be utilized in similar problems. These models were trained using ImageNet data which contains 1,000,000 images and 1000 classes to overcome the limitation of data and to reduce the training time[13]. These models can be used for image recognition based on transfer learning after fine-tuning these networks to the new problems. The learned weights of these pre-trained models are provided and used directly in the new problems[14]. The purpose of utilizing pre-trained models is to take advantage of learned features on a larger dataset, therefore the new model can converge faster and perform better with a smaller dataset. This gives us the advantage of DL independence of feature engineering over traditional methods without giving up the time, computational resources and cost effeciencies. Examples of these pre-trained CNN models are visual geometry group VGG (16, 19)[15], EfficientNet (B0 to B7)[16], MobileNet[17], and residual neural network (ResNet)[18], etc.

The contributions of this research can be summarized as follows:

- A framework has been developed to diagnose COVID-19 using chest X-ray images for both full and segmented images.
- A multiplication between each original image and the associated lung mask from the ground truth dataset provided by the database has been applied to get the segmented lung.
- Different image enhancement techniques have been applied to both full and segmented X-ray images to reach the best possible classification performance.
- CNN pre-trained models based on transfer learning have been used to classify both full and segmented chest X-ray images with all enhancement versions and achieved promising results.
- Since the purpose of utilizing pre-trained models is to take advantage of learned features on a larger dataset, therefore the smallest possible datasets that can achieve the best possible performance have been used for faster convergence.

Recently, many works have been developed to detect and diagnose COVID-19 and other lung diseases based on different medical image modalities using different machine learning techniques especially deep learning and transfer learning techniques. The purpose of all these works is to improve the performances of the methodologies used in the detection and classification of COVID-19 and other lung diseases. The focus in the research will be in X-ray images as the adopted medical image modality in this research.

The rest of the paper is organized as follows. Related COVID-19 articles using deep learning are reviewed in the "Related work" section. Then, the proposed framework for COVID-19 classification is described in "The proposed framework" section. Next, the results of X-ray images obtained with the proposed framework are presented in "Experimental results" section. The discussion and comparison with literature are provided in "Discussion" section. Finally, the main "Conclusions and future work" are outlined.

Related work

Recently, many works have been developed to detect and diagnose COVID-19 and other lung diseases based on different medical image modalities using different machine learning techniques especially deep learning and transfer learning. The purpose of all these works is to improve the performances of the methodologies used in the detection and classification of COVID-19 and other lung diseases. Where the proposed research will use X-ray images as a medical image modality, the focus in this section will be on the previous work based on X-rays.

Nishio, et al.[19] presented a system based on VGG16 to classify images of chest X-rays as healthy, COVID-19 pneumonia, and non-COVID-19 pneumonia. They applied the proposed system to 1248 X-ray images collected from 2 different public datasets. The collected X-ray images contain 500 healthy samples, 215 images for COVID-19 pneumonia patients and 533 images for non-COVID-19 pneumonia patients. The achieved accuracy was 83.6%, while the sensitivity was 90.9%.

Minaee et al.[20] applied deep learning to recognize COVID-19 cases using chest X-rays images. Transfer learning was used to train 4 CNN models which are DenseNet-121, SqueezeNet, ResNet50, and ResNet18 to binary classify images as COVID-19 or not. The training was applied to 84 (420 after augmentation) COVID-19 images and 2000 non-Covid images, while the test was applied to 100 COVID-19 images and 3000 non-COVID images. The best achieved sensitivity of these models was 98%, while the specificity was 92.9% for the SqueezeNet model.

Sahin[21] proposed a CNN model for binary classification of COVID-19 cases as COVID and Normal using chest X-ray images. Also, two pre-trained models which are ResNet50 and MobileNetv2 are applied to the used dataset of 13,824 X-ray images. The proposed CNN model achieved an accuracy of 96.71% and F1-score of