network according to the used chest X-ray data and to the current problem output which is (2/4) rather than 1000 in the ImageNet data. To avoid overfitting, a dropout of 0.3 was applied in the fully connected layers. Figures 5 and 6 illustrate the fine-tuned top layers based on VGG19 and EfficientNetB0 respectively for binary classification.

Performance evaluation

A benchmark dataset was employed to validate the performance of the proposed framework. For binary classification, a set of 1600 X-ray images (800 of each class) have been used to train CNN models using transfer learning. The dataset has been divided into three subsets training, validation, and test sets. The training set is used for learning the model and adjusting the parameters. The validation set is to test the model during the training phase and fine-tune the parameters. The test set is to evaluate the trained model. The division was done as 400 samples (25%) of the used X-ray images were selected randomly for testing (200 images for each class), and the remaining 75% samples were split again into training and validation splits (80–20%). For 4-classes classification, a set of 3200 X-ray images (800 of each class) have been used. Before training CNN models, different pre-processing steps were implemented to enhance the images of both full and segmented lungs chest X-ray images to investigate the classification performance of the CNN models using the different versions.

The following metrics were used for the evaluation of the different CNN models trained using various dataset versions:

$$\text{Sensitivity/Recall}(\%) = \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{1}$$

$$\text{Precision}(\%) = \frac{\text{Tp}}{\text{TP} + \text{FP}} \tag{2}$$

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

$$\text{Accuracy}(\%) = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FP} + \text{TN} + \text{FN}} \tag{4}$$

dense (Dense)	(None, 1024)	25691136
dense_1 (Dense)	(None, 512)	524800
dense_2 (Dense)	(None, 256)	131328
dropout (Dropout)	(None, 256)	0
dense_3 (Dense)	(None, 2)	514

Total params: 39,292,738
Trainable params: 26,347,778
Non-trainable params: 12,944,960

Figure 5. Fine-tuned top layers based on VGG19 pre-training model.

dense (Dense)	(None, 1024)	5243904
dense_1 (Dense)	(None, 512)	524800
dense_2 (Dense)	(None, 256)	131328
dropout (Dropout)	(None, 256)	0
dense_3 (Dense)	(None, 2)	514

Total params: 9,534,117
Trainable params: 5,900,546
Non-trainable params: 3,633,571

Figure 6. Fine-tuned top layers based on EfficientNetB0 pre-training model.