An Advanced Convolutional Neural Network for Detecting Chest X-ray Abnormalities

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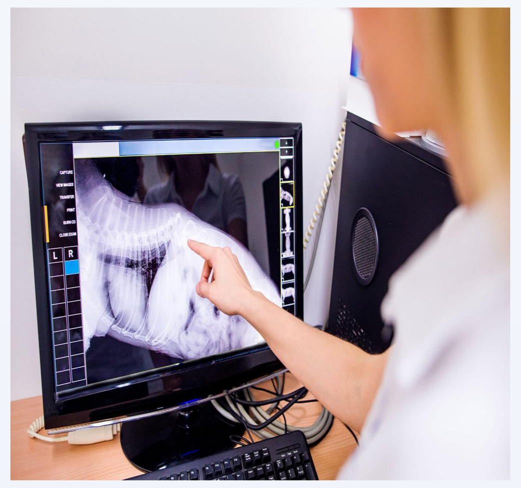
ABSTRACT

In the field of medical images diagnoses, doctors need a valuable second opinion when diagnosing thoracic diseases in chest X-rays. Existing methods of interpreting chest X-ray images classify them into a list of findings without specifying their locations on the images, resulting in uninterpretable results. Convolutional Neural Network (CNN) is a popular model for thoracic diseases diagnoses, which is a deep learning technique that has shown high accuracy in image classification and detection of features. In this work, an advanced CNN model is proposed to identify 14 findings in chest X-rays. For each test image, the intended CNN model should predict a bounding box and class for all findings. The classes range from 0 to 13, with each number corresponding to a specific disease in the dataset. Both numerical and visual results have demonstrated that the proposed model outperforms the CapsNet model with accuracy of 92.49% in X-ray images classification and labeling.

INTRODUCTION



Thoracic diseases are serious health problems that plague a significant amount of people. Chest X-ray is currently one of the most popular methods to diagnose thoracic diseases and plays an important role in the healthcare overflow [1]. Yet, as it happens when working with such a wide variety of medical Tools, radiologists face many daily challenges, perhaps the most being the chest X-ray. The interpretation of chest X-rays can lead to medical misdiagnosis, even for the best practicing doctor. Computer-aided detection is a technology designed to identify these diseases in X-ray scans and decrease the false negative rates of physicians interpreting medical images. This research has two specific aims:

1. Localize and classify different types of thoracic abnormalities from chest X-ray.
2. Build a valuable second opinion for doctors that could help accurately identify and localize findings on chest radio-graphs.

BACKGROUND

Convolutional neural networks (CNNs) were proposed by Yann LeCun in 1988 that have been widely applied to a variety of features detection, image recognition, medical diagnostics, etc [8]. Karnkawinpong et al. [3], compared three CNN architectures (AlexNet [4] /VGG-16 [5] /CapsNet [6]) that could help in early diagnosis of Tuberculosis infection. Mao et al. [7], built a deep generative classifiers architecture to diagnose thoracic diseases in chest X-ray images with accuracy of 90% after 10 epochs. Kieu et al. [2], employed 9 well-known convolutional neural networks to detect COVID-19 from chest X-ray images, VGG16 and VGG19 outperform other networks with accuracy of 92% in confirming positive cases.

METHODS

- VinDr-CXR dataset is used in this research, collected from two hospitals in Vietnam, between 2018 and 2020. A total of 18,000 scans in this dataset were split into 65.6% for training, 17.7% for validation, and 16.67% to test the accuracy of the proposed system.
- The advanced CNN model is built using keras library and contains 3 types of layers (Convolutional, Max pooling, and SoftMax). Batch normalization is used to reduce the training time by normalizing the inputs to a layer for each mini-batch. ReLU is the activation function that transfers the summed weighted input from the node into the activation of the node or output for that input image.

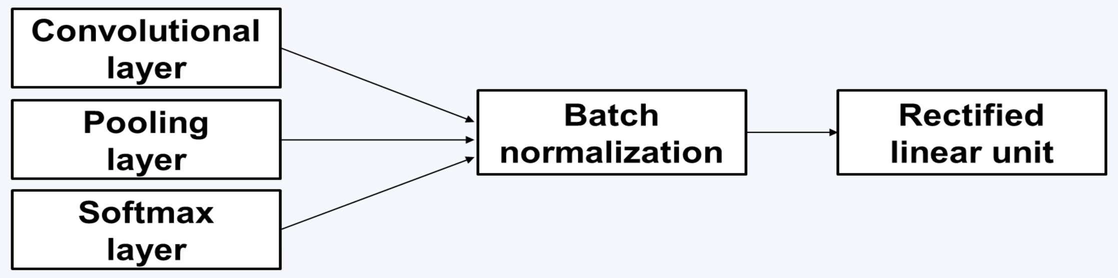


Figure 1: CNN model architecture

Preprocessing

In this phase, data is analyzed and prepared for training. This histogram indicates the amount of X-ray scans for each thoracic disease that exists in the dataset as well as the number of clear/normal scans.

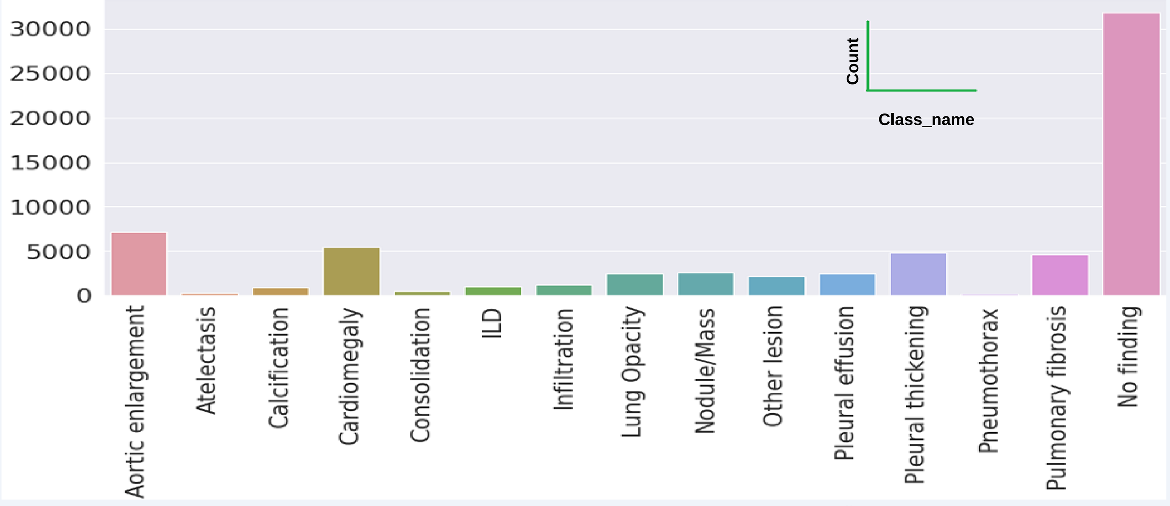


Figure 2: Histogram shows the number of each finding in the dataset

Also, it was found that the number of normal scans in the dataset is almost 3 times the number of abnormal cases as shown in figure 3.

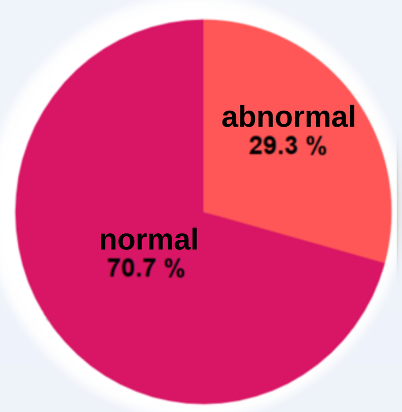


Figure 3: normal/abnormal scans percentage

Training

K-fold cross validation is used to estimate the performance of the model on unseen data. A total of 5 folds is done resulting different accuracy values. This table shows the accuracy and loss in each fold.

	loss	Binary_accuracy	val_loss	Val_binary_accuracy
Fold 1	0.3585	0.8406	0.4360	0.8525
Fold 2	0.2310	0.9081	0.1717	0.9250
Fold 3	0.2031	0.9190	0.2459	0.8933
Fold 4	0.1872	0.9264	0.3083	0.8825
Fold 5	0.1872	0.9249	0.1694	0.9233

Table 1: 5-fold cross validation results

RESULTS

- The CNN model classifies and labels 14 different findings (14 thoracic diseases, and the normal case) in each X-ray image. The 14 radiographic findings as listed below:

0 - Aortic enlargement
1 - Atelectasis
2 - Calcification
3 - Cardiomegaly
4 - Consolidation
5 - ILD
6 - Infiltration
7 - Lung Opacity
8 - Nodule/Mass
9 - Other lesion
10 - Pleural effusion
11 - Pleural thickening
12 - Pneumothorax
13 - Pulmonary fibrosis

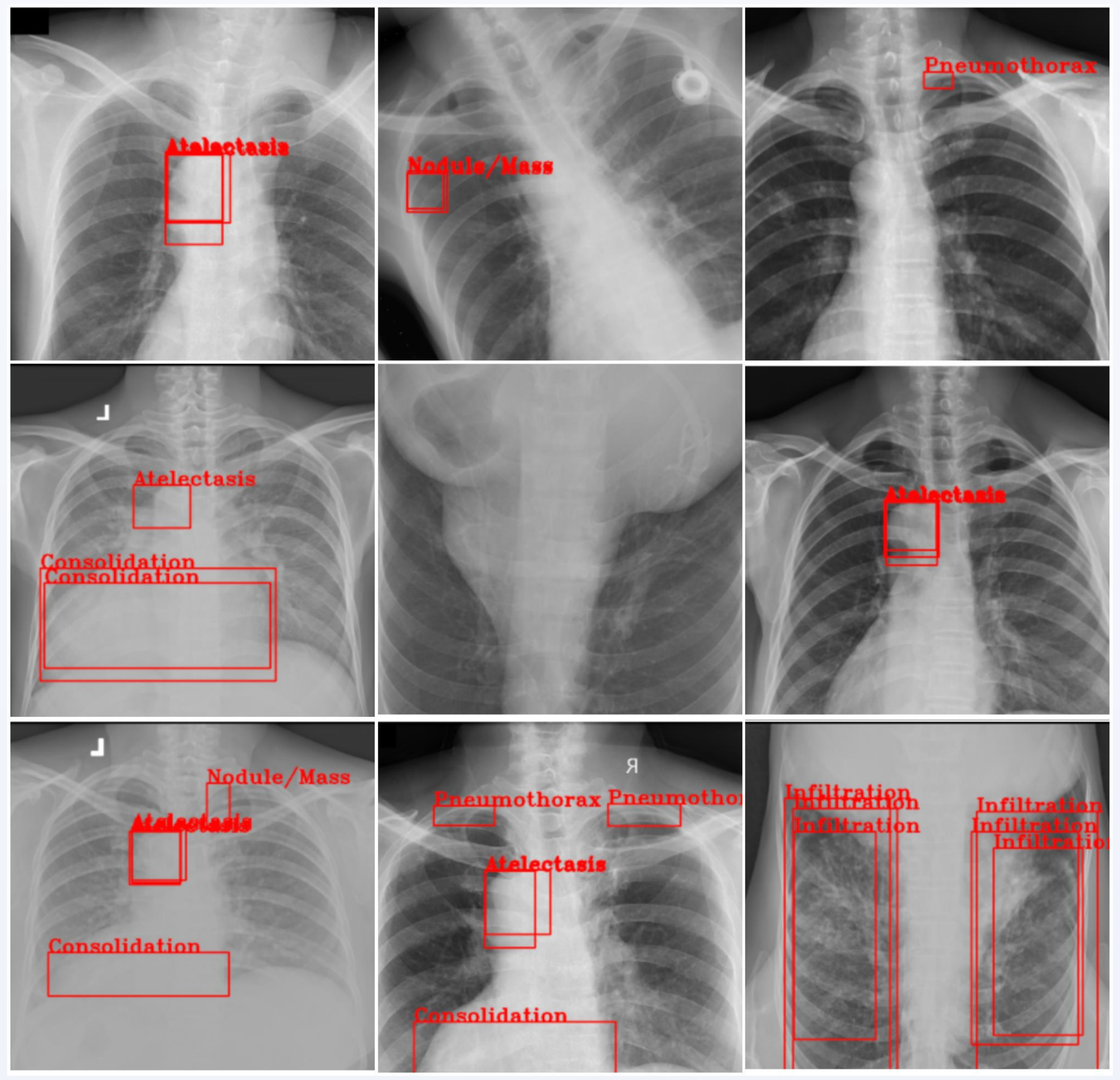


Figure 4: some examples of X-ray images classified and localized by the model and the image in the middle indicates no findings found (normal)

- In the training process, we evaluated the model on the validation set, and selected the model that achieved the highest classification performance to test on the test set. We repeated the training and classification procedure 5 times and reported that the model has reached 92.49% success in classification and detection. The loss factor decreases over time and is about 0.2 in the last cycle. The classification accuracy and the loss values are shown in the graphs below.

The blue line shows the training performance of the network, while the yellow line shows the test performance of the network obtained as a result of each cycle.

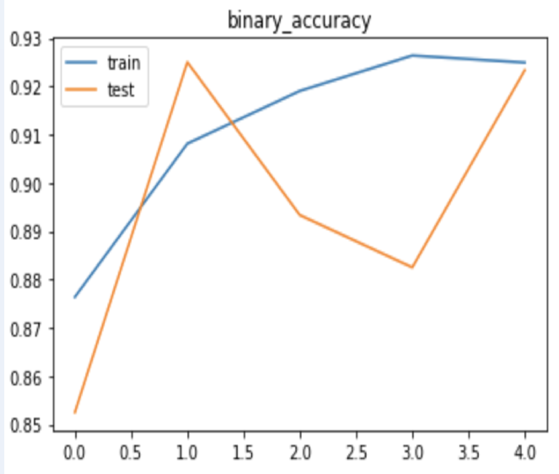


Figure 5: Accuracy graph

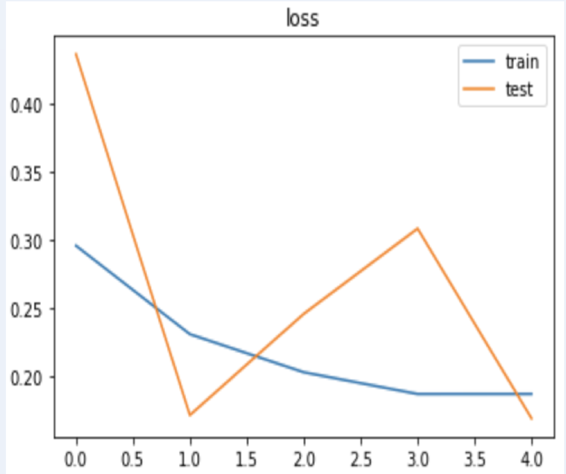


Figure 6: Loss graph

CONCLUSION

Chest disease is an area where mortality rates are high all over the world. Studies of detection and classification of thoracic diseases are important. In this study, chest X-ray images taken from VinDr-CXR dataset were performed as input data to the implemented model using data augmentation and histogram equalization techniques. In this research, an advanced Convolutional Neural Network is proposed. The proposed CNN model performs thoracic diseases classification and localization on chest X-ray images with a very low loss rate of 0.2 after 5 training cycles. The model outperforms the popular CapsNet model with accuracy of 92.5% and 86.86% for the CapsNet model.

FUTURE WORK

As a future work, a bigger dataset will be used for more training of the CNN model to get a higher classification performance. Additionally, 10-fold cross validation can be employed to get a better approximation of optimum model accuracy since only 5-fold was done in this research.

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