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ResNet based Lung Nodules Detection from Computed Tomography Images

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Abstract*: Lung cancer have become one of the major threat to human kind over few years. The survival rate of the patient depends mainly on the stage of cancer when it was detected with early stage detection increases survival rate significantly. Many computer aided detection systems were proposed to assist radiologist in detecting lung nodules efficiently. After the success of deep learning neural network in object classification problem, researchers started adopting it for different tasks in medical image processing and hence in lung nodule detection systems. Hence, a lung nodule detection method using ResNet in CT images is proposed. The proposed method consists of two stages, the pre-processing stage and nodule detection stage. The proposed technique uses morphological operations for segmentation of lungs and convolutional neural network for detection of lung nodules. This method is developed with an aim to provide second opinion to radiologists and reduce their workload. LIDC (Lung Image Database Consortium) dataset which contains 1010 CT patients images of chest regions are taken for experimentation. The model was able to achieve top-5 accuracy of 95.24% on test dataset.

Keywords: Lung Nodules, Convolutional Neural Network, Deep Learning, Nodule detection.

I. INTRODUCTION

An estimated 18 million cancer cases were registered in 2018 throughout the world out of which 9.6 million patients deaths was estimated as noted in World Health Organization's (WHO) and Lancet reinforced Report [1]. Lung and breast cancers top the list of all types of cancers diagnosed in 2018 with 12.3% of the total number of patients in each category. Among them, Lung cancer is estimated to claim one in every five deaths due to cancers and tops the mortalities list.

In general, the abnormal development of cells inside the lung region is called as pulmonary nodule or lung nodules. These nodules are detected by radiologist with the help of non - invasive imaging processes like computed tomography (CT) scans, where nodules result in a radiographic opacity.

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To assist radiologist with this task many computer – aided - diagnosis (CAD) systems that automatically detects lung nodules are developed.

The objective of this research work is to detect potential lung nodule using Deep convolutional neural network. The aim is to develop 2D convolutional neural network based on ResNet for lung nodules detection. The CAD system will be able to detect the presence of a nodule (including tiny nodule < 3 mm in diameter for early stage cancers) from a 512 x 512 pixels 2D lung CT scan. The slice of CT scan along with lung nodule is shown in figure 1. The CAD system developed will consists of two stages, lung scan preprocessing and Nodule candidate's detection.

II. LITERATURE SURVEY

Finding exact location of possible nodules in the lungs is called nodule detection. A location is a set or range of points in (x,y) coordinates in a 2D plane of a slice in which the nodules lies. Our aim is to find these locations. After the success of deep convolutional neural networks (DCNN) AlexNet [12] in image classification challenge which was developed by Alex Krizhevsky, researchers started to use DCNNs for various different computer vision tasks. These DCNNs are in general referred as "deep learning". Deep learning architecture also found great success in medical imaging applications and so many CAD systems for detecting lung nodules also were developed using deep learning architecture. In [2] a framework with 2D convolutional neural network (CNN) for automated pulmonary nodule detection was proposed. A Faster R- CNN was used with two region proposal networks followed by a deconvolutional layer to detect nodule candidates. False positive reduction is done by three models along with boosting architecture based on 2D CNN. The results are fused to vote out final classification result. A fast and fully-automated end-to-end system was proposed in [4] that can efficiently segment lung nodule contours from raw thoracic CT scans. This system had four modules which are candidate nodule detection with Faster regional-CNN (R-CNN), candidate merging module, false positive (FP) reduction module with CNN, and nodule segmentation module with customized fully convolutional neural network (FCN). The nodule detection accuracy achieved with this method was 91.4% and 94.6% with an average of 1 and 4 false positives (FPs) per scan. A 2D DCNN is used in [6] was able to detect 60.1% of all the nodules with average of 2.1 false positive per scan. In Hamidian et al. [5] a 3D DCNN is implemented with sensitivity of 80% and 22.4 false positives per scan.

In [7] a multi-level 2D MU-Net was used which gave sensitivity of 94.3% but had 214.9 average number of candidates per scans. A vanilla 3D DCNN was implemented by [9] which they named it as DeepMed had a sensitivity of 93.8% with 4 false positive per scans.

In [10] a 3D DCNN with multi-scale prediction strategy was used to get 93.4% sensitivity with 4 false positive per scans.

III. DATASET

The chest CT scan dataset from LIDC-IDRI public archive was used for experimentation. It was created with the collaboration of 7 academic centres and 8 medical imaging companies. This dataset consists of lung cancer screening thoracic computed tomography (CT) scans of 1010 cases with associated XML files of radiologist annotation. The annotation was done by four experience thoracic radiologists in two phases (blind and open diagnosis). Each case of lung cancer screening consists of a variable number of slices ranging from 100 to 450 depending of scan thickness. Each slice consists of 512 x 512 pixels array which forms the image of chest region for that slice. These slices are provided in Digital Imaging and Communications in Medicine (DICOM) format. DICOM format is standard to store, transmit, print, process and display medical images.

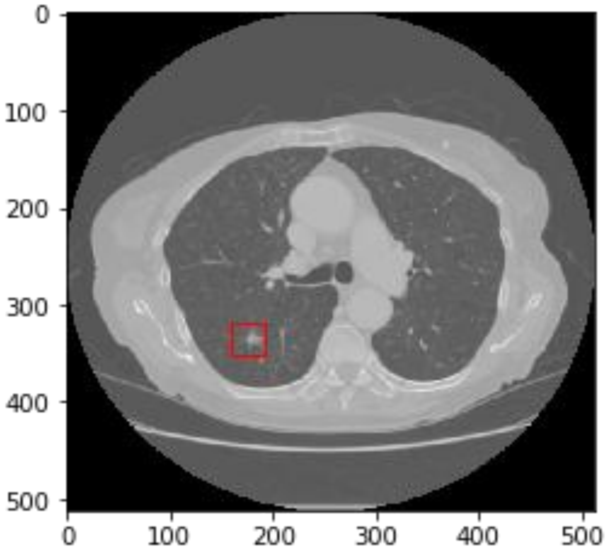
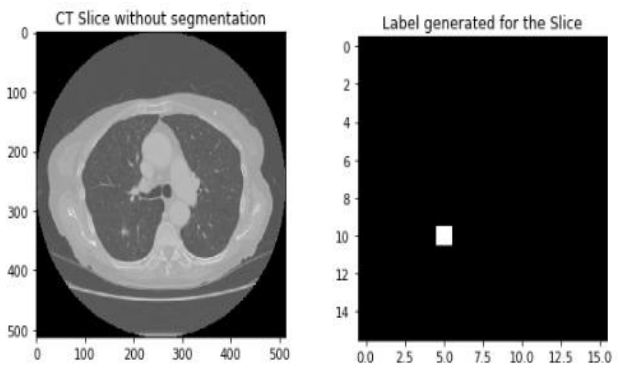


Fig. 1. Slice of pulmonary CT scan. Red box shows the lung nodule.



(a) (b)

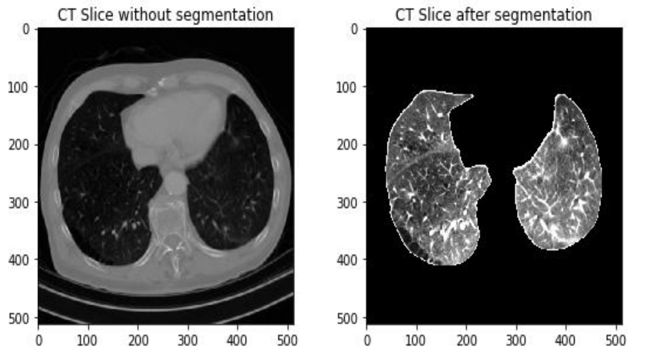
Fig. 2.(a) Slice of CT scan (b) Generated label from the annotation given in XML files.

IV. PROPOSED METHOD

The proposed method consists of two stages. The first stage is to preprocess the slice of CT scans to segment out human tissues, organs, bones etc. from lungs. After segmentation, the slice of 512 x 512 pixels is divided into 32 x 32 pixels windows giving total of 16 * 16 windows. These windows are used to generate heatmaps indicating nodules for that window based on annotation provided in xml files which were used as labels for training DCNN. The labels and 2D CT slices are shown in figure 2.

A. Pre-processing and Segmentation

The pre-processing and segmentation stage consist of sequence of steps to segment out bones, tissues, air gaps, blood vessels etc., from ct slice. The first step is to convert Hounsfield units (HU) value of -2000 into 0 as voxels with this value are outside of the bore of the CT scanner. Next, a thresholding with a threshold HU value of 600 is used to convert the slice into binary image. From the binary image two regions with largest area are extracted. An erosion operation followed by dilation and then closing operation is performed to generate mask for segmentation. This mask is superimposed on slice to segment lung region from the slice. The original 2D scan slice with the slice after preprocessing is shown in figure 3.



(a) (b)

Fig. 3. (a) Slice of CT scan without segmentation (b) Slice of CT scan after segmentation.

B. Nodule candidate detection

The second stage of the proposed system is nodule candidate detection stage. A 2D DCNN architecture based on ResNet was proposed for detecting nodule candidates from CT scans. The DCNN which is proposed starts with 512 x 512 input layers followed by six modified residual blocks with maxpooling layer separating them. The first four modified residual blocks consists of two 2D convolutional layer sandwiched between batch normalization layer. The fourth residual block contains only one 2D convolutional layer and finally the last block consists of four 2D convolutional layer. To equate the number of filter of input and output of residual block, the shortcut path also has a 2D convolutional layer.

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These residual blocks are finally terminated with dense layer which outputs 256 nodule candidate probabilities, each for every 32 x 32 window. The proposed DCNN architecture is shown in figure 4.

V. EXPERIMENTAL RESULTS

The proposed system is evaluated on the LIDC-IDRI dataset which consists of 1010 chest CT scan cases. Out of 1010 cases, first 500 cases are selected for experimentation. The slices with nodule candidates are considered and all other slices without nodule candidates are ignored. These slices are divided into 3 batches each for training, validation and testing. The database is divided into 70 % for training process and 30% for testing the proposed method. The training process dataset of 70% is further divided into 80% for training and 20% for validation in training process.

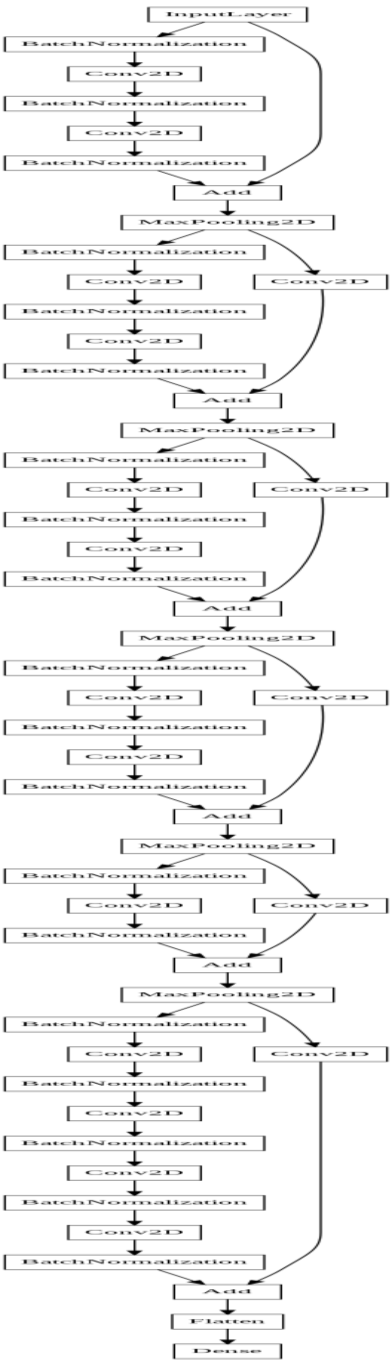

Fig. 4. ResNet based Deep Convolution Neural Network.

The method was trained and tested on system with Tesla K80 GPU and RAM of 25 GB. Adams optimizer with 0.001 learning rate was used to train the model for 40 epochs. Figure 5 displays the result with top 5 predictions of the model along with the annotation of radiologists on some samples. The accuracy of the proposed system against candidates per scan is shown in figure 6. The figure indicates that the accuracy of the system increases considerably until 5 candidates per scan after which it become almost constant giving best performance at 5 candidates per scan. Table – I gives the comparisons of the proposed method with other existing methods illustrated in [13].

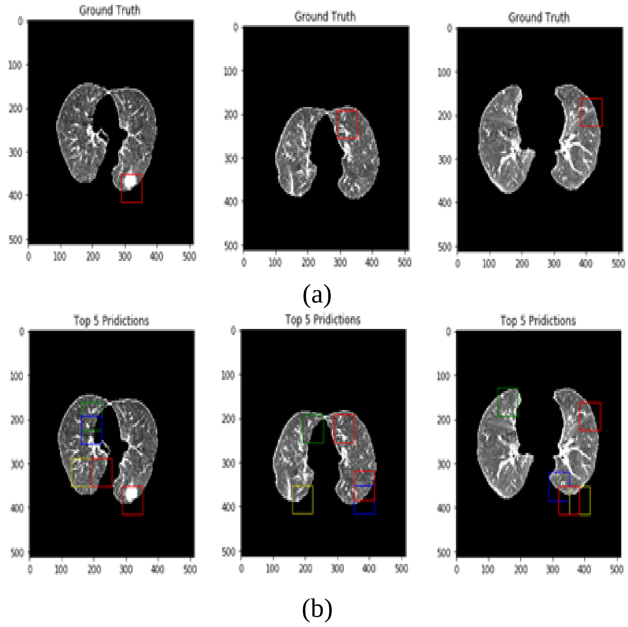

Fig. 5.(a) CT scans slices with ground truth. (b) Top 5 predictions with top 1 to top 5 shown as red, green, yellow, blue and orange bounding boxes.

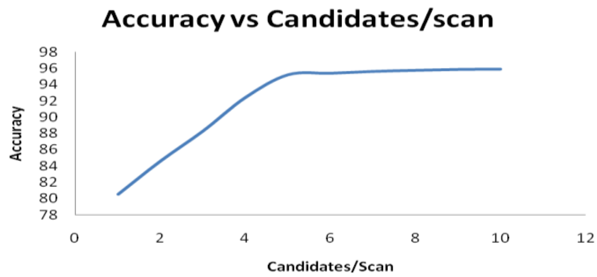

Fig. 6. Accuracy vs number of candidates per scan of proposed method.

Table – I: Comparison of deep learning based CAD systems for lung nodule detection system.

System	Accuracy	Candidates/Scan
ISICAD	85.6	335.9
Subsolid CAD	36.9	290.6
Large CAD	31.8	47.6
ETROCAD	92.9	333.0
R-CNN	94.6	15.0
Proposed System	95.24	5.0

VI. CONCLUSION

In this paper, a ResNet based 2D deep convolution neural network for pulmonary nodule candidate detection was proposed. Experimentation result on 500 cases from LIDC-IDRI dataset shows that the proposed system produces comparable result with just two stages. A simple method based on morphological operations was adopted for segmentation which saves both computation time and cost. The nodule detection stage is based on ResNet with fewer residual blocks. This method questions the need for false positive reduction stage. In future, the method can be tested on the real time dataset. Different DCNN architecture can be implemented for nodule detection stage to show the effect it has on final result.

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