COVID 19 Severity of Pneumonia Analysis Using Chest X Rays

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2020 IEEE 15th International Conference on Industrial and Information Systems (ICIIS) | 978-1-7281-8524-8/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICIIS51140.2020.9342702

***Abstract* -- Purpose: To identify pneumonia location and determine the severity of pneumonia using deep learning network on chest X-ray images Methods: Data from RSNA Pneumonia detection challenge [1] from Kaggle is used for train and test analysis. Identifying images and calculating severity percentage of lung opacity in pneumonia present images by drawing bounding box Results: With 4668 X-ray images trained and tested on 1500 X-ray images, initial model has shown a mean average precision (mAP) of 0.90 on train set and 0.89 on test set. Conclusion: The intention is to leverage on existing studies and develop a better performing and highly accurate deep learning model to calculate severity percentage in a pneumonia present chest x-ray image.**

Keywords— COVID19, Chest X-Ray, mask_RCNN, neural network, pneumonia, severity detection.

I. Introduction

Coronavirus also known as COVID 19 [2] [3] [4] is a highly contagious disease caused due to severe acute respiratory syndrome corona virus 2 (SARS-CoV-2), previously known as 2019 novel coronavirus (2019-nCoV), one of the species of corona virus.

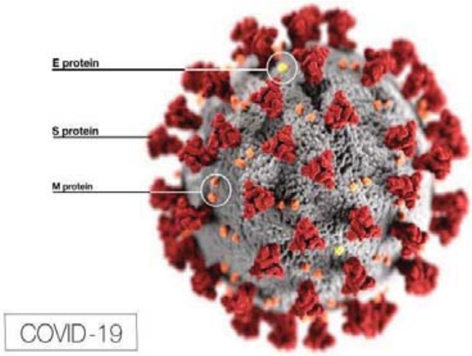


Fig. 1. Labelled microscopic image of COVID19

On 11 February 2020, the condition was named by WHO as COVID-19. Coronaviruses (CoV) [5] are a large group of viruses causing illness ranging from common cold to more severe diseases such as Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV). A new strain that previously wasn't identified in humans is the novel coronavirus (nCoV).

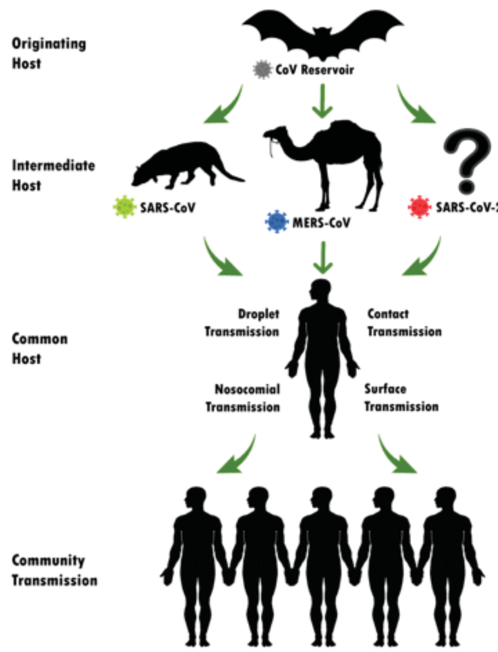


Fig. 2. Transmission of viruses from animals to humans and its spread [8]

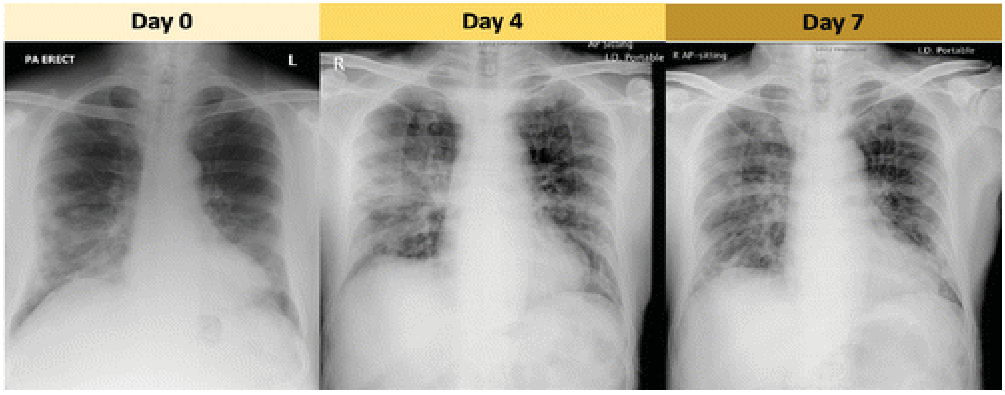


Fig. 3. Chest radiographs of an patient from China, elderly and male, who travelled to Hong Kong. Three chest X- ray images were selected out of the daily acquired images. The consolidation in the right lower zone on day 0 persist into day 4 with new consolidative changes in the right midzone periphery and perihilar region. The midzone change improves on the day 7 image [10]

Fig. 2 Show the transmission of COVID19 from animals to humans specifically from bats. In theory it was transmitted to humans due to consumption of bat mean sold in wet markets. It is believed to have zoonotic origins which are genetically closely similar to bat coronaviruses, suggesting that COVID19 emerged from viruses present within bats [7].

Patients infected with virus show regular symptoms of cold, fever, cough, respiratory issues like shortness of breath, difficulty in breathing. As severity of infection increases patients can have pneumonia, severe acute respiratory syndrome, dysfunction of kidneys, etc. leading to death [5].

Patients with respiratory symptoms are advised to stay isolated and undergo further clinical examination known as Reverse Transcription Polymerase Chain Reaction. The PCR testing [9] which takes hours to receive results is the medical standard to identify COVID-19.

With the growing number of cases walking into hospitals, alternatively, chest X-ray is used as initial element to review clinical situation of a patient. If the X-ray shows any pathological findings, patients are admitted for further diagnosis. If the X-Ray is normal, patients are requested to go home and wait for PCR test results

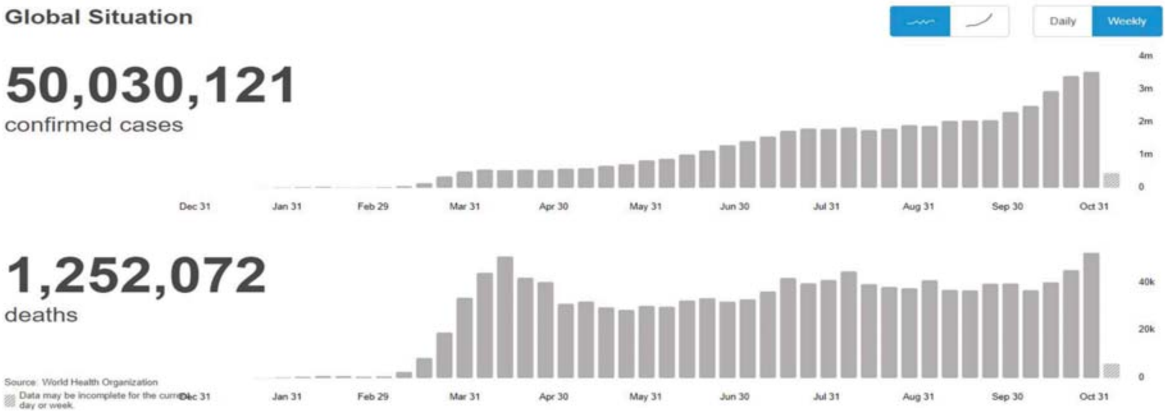


Fig. 4. Global Scenario from WHO Coronavirus Disease (COVID-19) dashboard [5] as of 9th November 2020

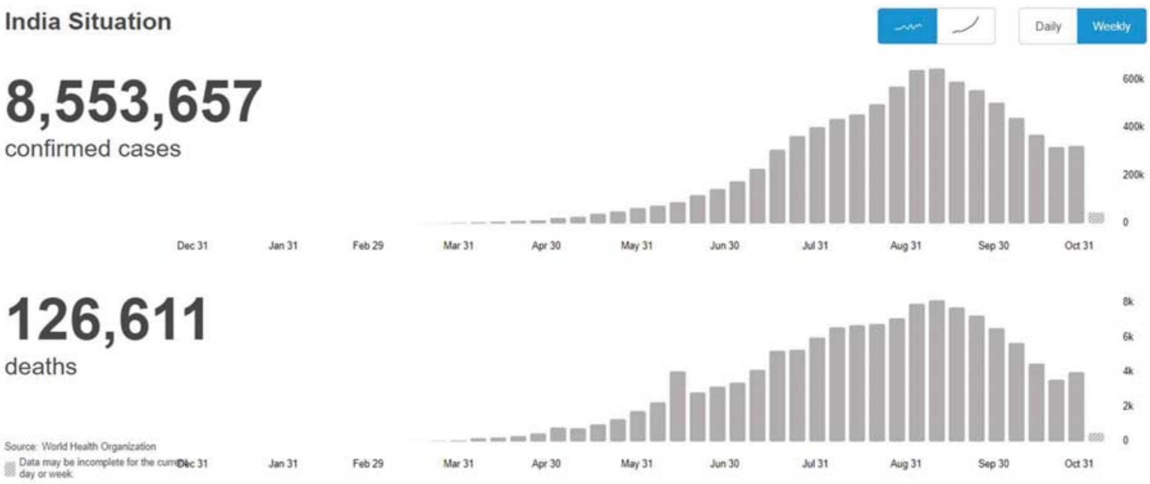


Fig. 5. Indian Scenario from WHO Coronavirus Disease (COVID-19) dashboard [5] as of 9th November 2020

The X-ray findings in Fig.3 strongly suspect presence of COVID-19 infection with a pattern that is similar to ground glass area, which affect both lungs, especially in the posterior segments in the lower lobes and with a fundamentally peripheral and sub-pleural distribution in initial stages.

Radiology is playing critical role to identify, if a patient can go home to wait for test results (or) get admitted for further observation. One of the roadblocks using X-ray is the availability of the radiology expert to interpret the image.

Inspired by the Artificial Intelligence (AI) technology and to assist radiology experts to interpret images in much faster rate & improved accuracy, proposing deep learning system (Mask R-CNN) to analyze images and detect patterns of COVID-19 in patients.

The current COVID-19 pandemic is unprecedented and as we see this is having a profound impact on the World as seen in Fig.4. It is the most serious public health crisis and the most significant geopolitical event of current generation.

The need for continued access to research and learning has never been more important. Especially for India, which is second highly populated country and currently under lock-down, which has reported close to 59,662 cases and 1981 deceased as on May 10, 2020 [5] due to COVID-19 so far Fig.5, is preparing for the worst. From one of the projections[11], it is stated that India might have to deal with ~300 million cases out of which more than four million could be severe. With an AI built CNN network, identifying individuals and assisting in time is a possibility. This in turn will have a greater impact on experts concentrating on severe cases to avoid further spread of the pandemic.

With Deep learning techniques like Mask RCNN, X-ray images can be more accurately and efficiently diagnose the disease by understanding the severity and type with pattern. In the current model, data set used with X-ray images are (a) Pneumonia, (b) No Pneumonia & not normal, and (c) normal types.

(a)

(b)

(c)

Fig. 6. (a) lung opacity-pneumonia, (b) No Lung opacity/not Normal

(c) normal

II. Material and Methods

A. Dataset

Dataset used for building the model is from a Kaggle competition – RSNA [1] Pneumonia Detection Challenge. The Radiological Society of North America (RSNA®) wished to improve efficiency of diagnostic goods services, reached out to Kaggle's machine learning community, also the US National Institutes of Health, The Society of Thoracic Radiology, and MD.ai were in collaboration to build a dataset that is rich in quality for the real life challenge.

B. Image Analysis

Initial images received from the dataset are in the DICOM format. These are the medical images which are stored in a special format known as DICOM Files (*.dcm). They contain a combination of header metadata as well as underlying raw image arrays for pixel data. Most of the standard headers containing patient identifiable information have been removed. Understanding the data structure, imaging file format and label types, primary objective is to detect the bounding boxes consisting of binary classification i.e. presence (or) absence of Pneumonia. The classes from dataset being divided into pneumonia (lung opacity), No pneumonia (lung opacity - not normal), normal. Even though the dataset is multiclass, used a binary classification to detect pneumonia positive (or) negative. If positive, what is the ROI defining the severity of Pneumonia.

III. Results

MASK-RCNN [12]: For every instance Mask RCNN generates high quality segmentation mask along with detecting objects in an image. Mask-RCNN adds a branch for segmentation mask prediction in a pixel to pixel method on every ROI i.e. Region of Interest, continuing with existing classification branch and bounding box regression. A framework with fast inference & training time, Mask R-CNN provides a varied range of flexibility in architecture designs and strength.

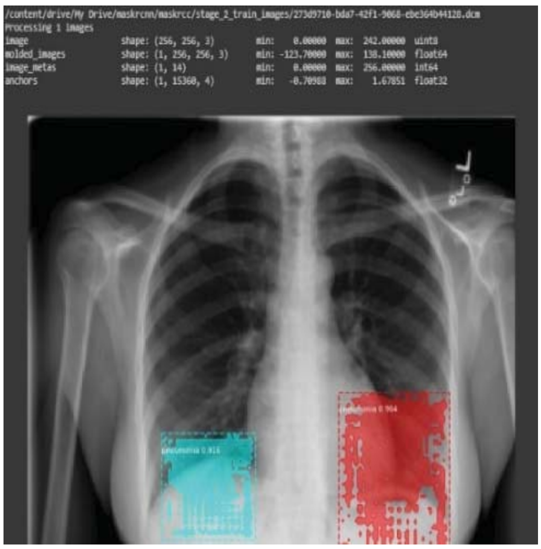


Fig.7. ROI defining the Severity Detection

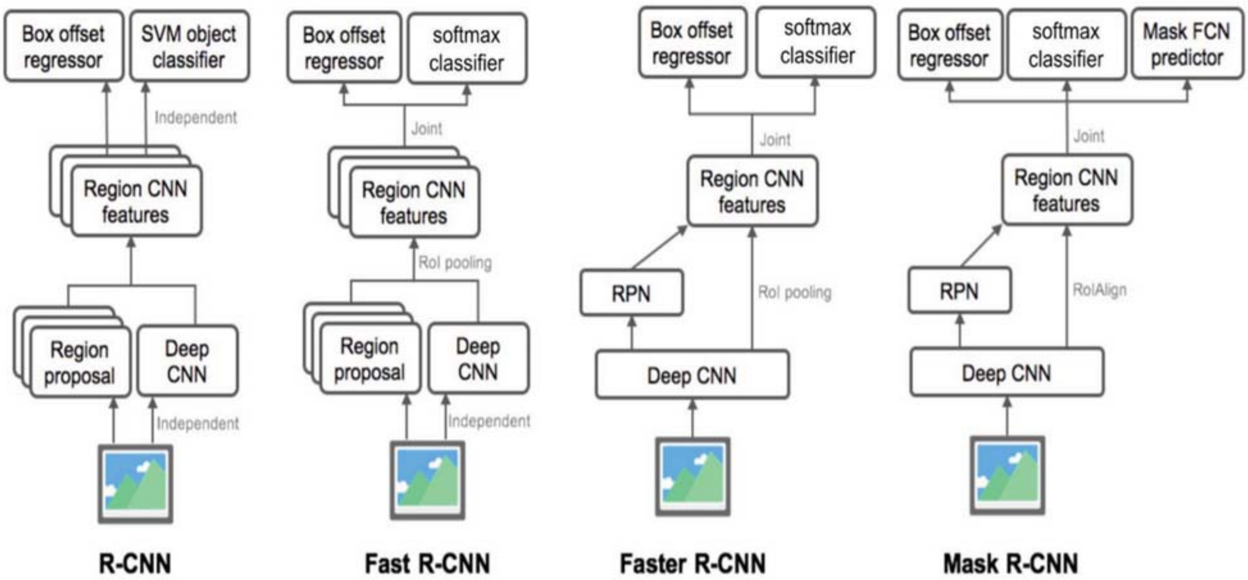


Fig. 8. Types of R-CNN Models [13]

Architecture built with DenseNet as Backbone, a convolutional network for feature extraction and for Bbox recognition (both regression and classification) an FPN, to each region of interest is applied with mask prediction separately, on the entire image.

Why Mask-RCNN [14]: Mask-RCNN has quickly developed segmentation results with object identification within a short span of time. Mostly, the advancements are improved from baseline networks, like Fully Convolutional Network (FCN) and Fast/Faster RCNN frameworks for segmentation and object identification respectively. Such type of method is practically in-built with fast training and interpretation on the data.

Mask RCNN includes a branch for segmentation masks prediction on every region of interest (RoI) when compared to Faster RCNN, along with a branch for classification and Bbox regression (Figure 7) which was already an existing part of network. A small FCN is applied to every region of interest, at a pixel level, segmentation mask is predicted with the mask branch. Mask RCNN enables varied architectural designs that are flexible and applying the network to train a model is simple.

Furthermore, the mask branch ensures swift testing and only adds a small computational overhead in the process, enabling a fast system.The Mask branch is crucial for improved results, which makes Mask RCNN, a developed version of Faster RCNN. It is to be noticed that the pixel to pixel configuration in the network i.e from inputs to outputs is not structured in Faster RCNN. It is obvious on how region of interest pool, in fact coarse spatial quantization for feature extraction is obtained by the fundamental operation of attending to instances.

Predict m x m mask from each region of interest using a Fully Convolutional Network, allowing each layer of the mask branch to maintain the explicit spatial dimensions (m x m object). This architecture (in Fig. 8) requires fewer parameters in modelling which assures shorter runtime.

Pixel-level segmentation provides added advantage of predicting the severity of the lung damage by analyzing area of the masks from X-Ray images. Test Metrics used is mean Average Precision (mAP). Based on mAP values, Mask-RCNN outperforms winners of COCO (Common Objects in Context) challenge in shorter runtime

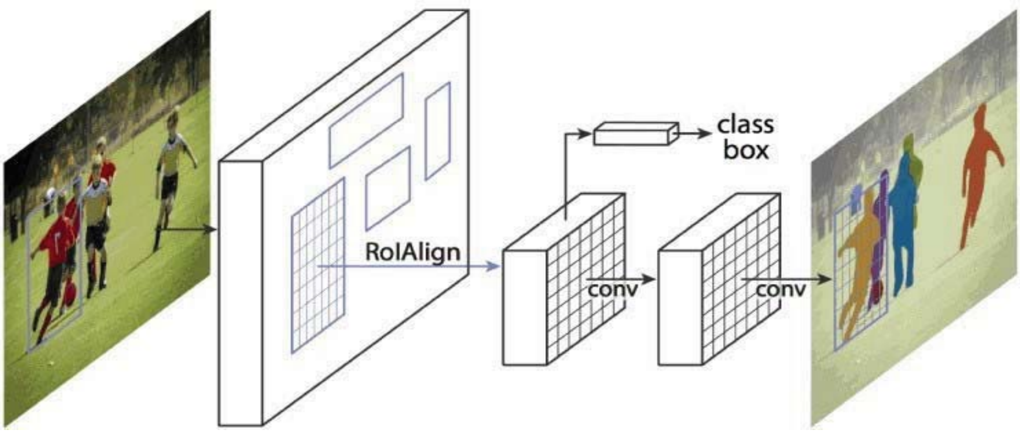


Fig.9. Mask R-CNN Architechture

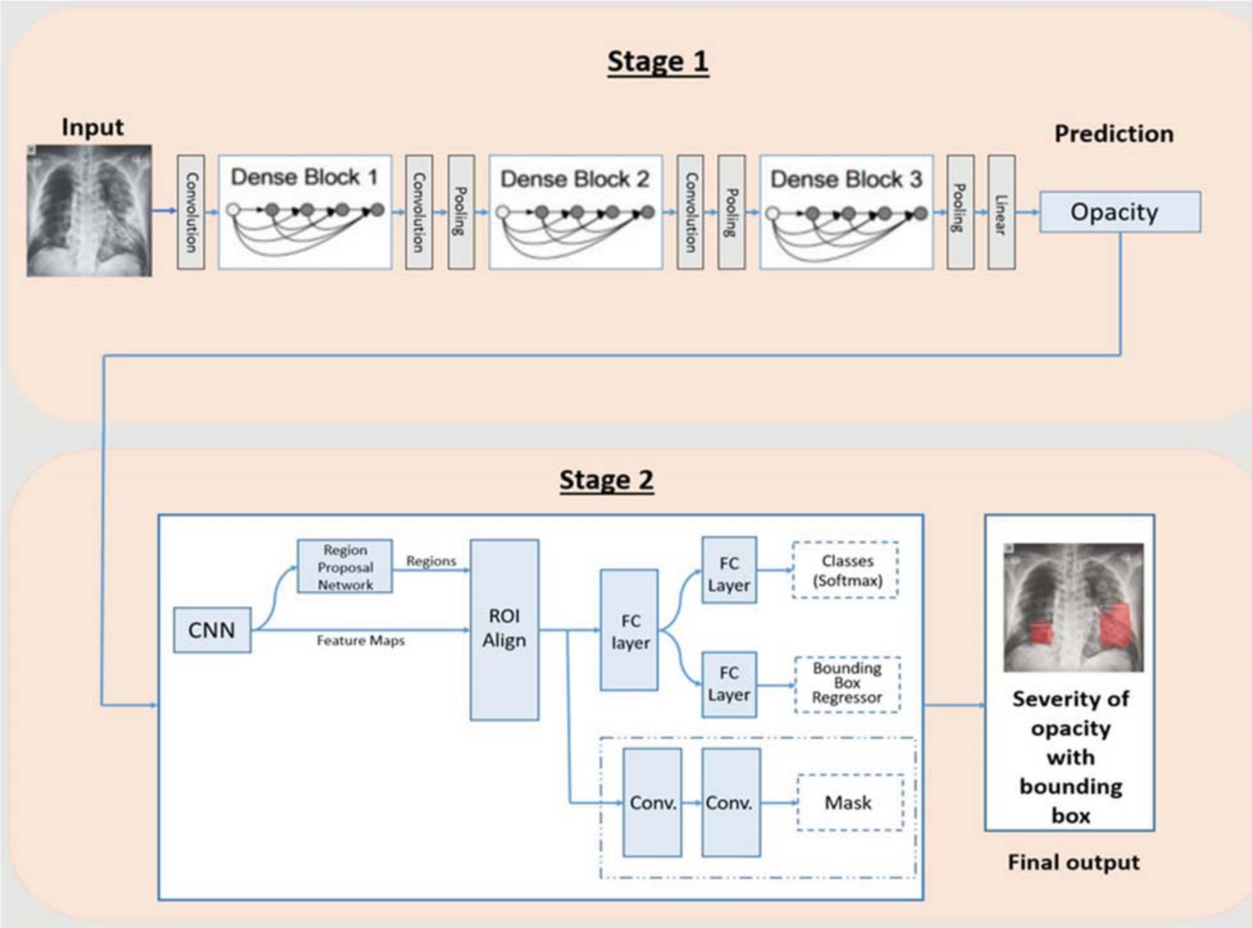
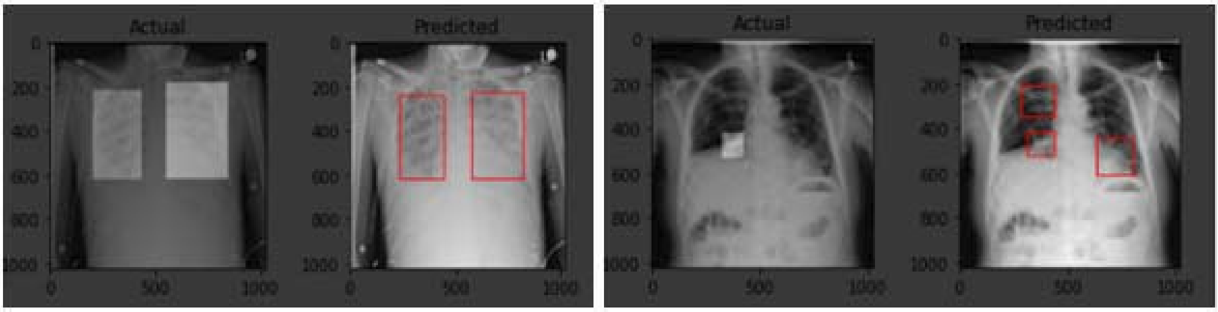
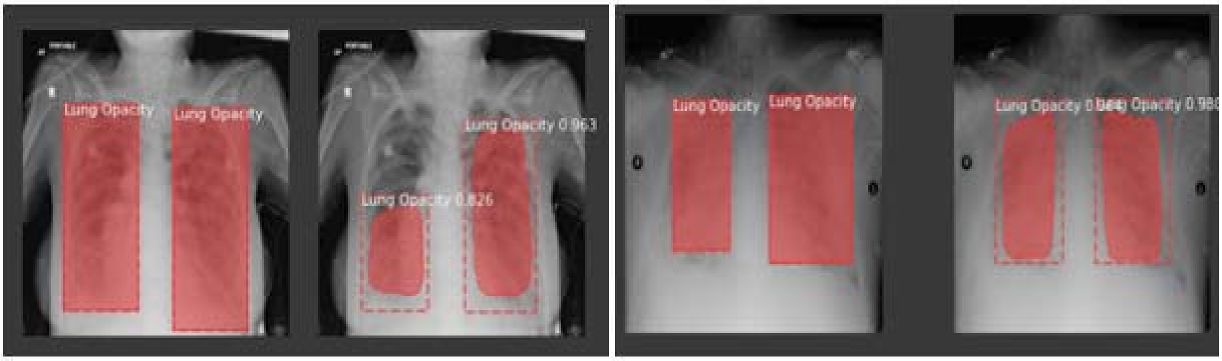


Fig. 10. Model Flowchart



(a)



(b)

Fig. 11 (a) Output of stage 1 (b) Output of stage 2

IV. DISCUSSION

Stage 1: A basic object detection model is employed to distinguish between images of patients having lung opacity and those not having lung opacity. The input to the model at this stage includes all the X-ray images belonging to normal patients, patients having pneumonia, caused due to various other reasons than the virus and also images belonging to novel corona virus.

The output out the model is that it simply highlights, with the help of a bounding box the area of the lungs where opacity is present. Opacity indicates the presence of a substance instead of air within the lungs, this is a characteristic of an abnormality caused due to pneumonia and COVID19.

The purpose of the first stage was to have a head start while diving into a relatively new topic, it was reassuring to start with a familiar task of object detection. An alternative motive was to feed the second stage of the project with only the images containing some amount of opacity so as to improve the accuracy of stage2.

Stage 2: In this stage a mask RCNN network is used to highlight the specific areas of the lungs where opacity is present as well as the severity of it, and this was done at pixel level.

The base network generates feature maps of the input image; these feature maps are send to region proposal network (RPN) simultaneously. The RPN is basically a CNN network which generates region proposals for each feature map.

These region proposals are sent to the ROI align layer where coordinated of bounding boxes and anchors are resized and aligned according to the dimensions of the feature map. The output of RoI align layer is given to two different network heads, one used for detection of class and finding coordinates of bounding box while the other is used to generate mask.

Implementing Mask RCNN network with 4 classification of Anchor pixel sizes of 16, 32, 64, 128. With these anchors trying to identify ROI with bounding boxes (Fig. 9). Baselining the [5] COCO dataset, pre-trained weights with the original dataset of +30000 train images. Experimented the model to train dataset size of 4668 images and reviewed the model performance on a test dataset of 1500 images.

Dataset has a combination of lung opacity, not normal and Normal classes in following composition i.e. 55:25:20 ratios with total dataset size of 6168 Setting the rate of learning of 0.006 with 200 step size for first 6 runs of epochs during model training.

Later, reduced the rate of learning to 0.001 with 200 step size for next 10 epochs during model tuning. For last 4 epochs, further reduced the learning rate to 0.0006 for the steps size of 200. The bounded box (as shown in below image) is marked to understand the severity by given the percentage on lung opacity (before and after segmentation of images). Achieved mAP (mean Average Precision) of .90 on Train set & .89 on Test set.

V. CONCLUSION

The intention is to leverage on existing studies and develop a better performing and highly accurate deep learning model to calculate severity percentage in a pneumonia present x-ray image of the lungs. The purpose is to track the target accurately and show the percentage of the severity. This can guide doctors, radiologist to perform more accurate diagnosis on patients to save time and improve on consistency of treatment. In this study, developing a model on X-ray images to understand the severity of the pneumonia with bounded box around the diseased area.

Making investigations more explainable in an attempt to gain deeper insights. One could use these bounding boxes to train a Mask RCNN to not only classify images with pneumonia, but also identify where in the image pneumonia is located**.**

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