Capstone Project – May/June 2021

Pneumonia Detection via Computer Vision



# Goal Statement



To help medical advisors detect pneumonia in

patients easily, by building an algorithm around

computer vision. Hence helping them to detect and

treat patients quicker by automating the process.

# Objective

Pneumonia is an infection in one or both lungs. Bacteria, viruses, and fungi cause it. The infection causes inflammation in the air sacs in your lungs, which are called alveoli.

Pneumonia accounts for a large number of deaths amongst children Internationally. It is detected through a medical process called chest radiography (CXR). This process is complex in the medical world due to numerous other lung conditions along with pneumonia hence not providing accurate results. The process is even more challenging as it has to be handled by only highly trained specialist medical advisors.

Due to this complexity, we would need to devise and automate an algorithm around detecting pneumonia, through bounding boxes in-order to help physicians make better decisions or even replace human judgement.

We would need to treat the respective data to develop an automated machine learning model, inorder to help medical advisors take quicker decisions/actions in treating patients as well as reducing the overall death rate.

Pneumonia accounts for over 15% of all deaths of children under 5 years old internationally. In 2017, where 920,000 children under the age of 5 died from the disease. We foresee our study via building a computer vision algorithm.

# 3. Data Structure

There are 4 datasets present with other observations to:

1. On analyzing and preparing the data we noticed that images are of the same size and shape, hence making the process of handling the images easier without having to change dimensions.
2. Each patient has multiple entries, which means patients can have one or more than one bounding box showcasing the infected area via their x-ray images.
3. With regards to image coloring, we observe that the images are gray scaled and do not really have “RGB” color code present within them.
4. Train labels - consisting of (x,y, width, height & Target column), which has 30228 rows and 5 columns in total.
5. Class info - consisting of (patientId and class column), which has 30227 rows & 2 columns in total.
6. Train Images - consisting of 26684 images
7. Test Images - consisting of 3000 images
8. **Summary of the Approach to EDA and Pre-processing**

We first analyzed and understood the data provided to us in the form of csv files and dicom images. This was to understand what could be our best possible approach and how we would need to use the information provided to us.

Started off our approach by selecting google colab as our building platform for the entire project. We set the “path” to load the required datasets from google drive, after mounting the drive platform in our notebook. Looking at the information provided, our first job was to import and load all necessary libraries and data packages inorder to move ahead with our analysis. On importing the same we took to first tackling and observing the csv datasets namely (train\_labels & class\_info).

* class\_info – We set the path to load the dataset from google drive. On importing we ran basic eda commands and observed that the dataset consists of (30227) records of various patients & 2 columns namely (patientId & class). The datatype for both is of the object class. With reference to null values, we notice that there are none present, hence clearing us from tackling missing values within the dataset.
* train\_labels – On importing the dataset and observing it we find that it consists of (30227) records of various patients too & has 6 columns within namely (‘x’, ‘y’, ‘width’, ‘height’) which pertain to the bounding box size, for each patient detecting their infected areas. With reference to null values, we notice that there are many patients with NAN values present (20672), which ideally shows no bounding box coordinates are present for them. Hence, we need to tackle this information by analyzing whether these values need to be imputed and not dropped, so that we do not lose vital information thereby hampering our overall model accuracy.

Moving on as per the total number of images present of patients, we have defined a code and displayed it via a dataframe as to how many bounding boxes patients have. We can observe that (23286 have one bounding box), (3266 have two bounding boxes), (119 have 3 bounding boxes) & (13 have 4 bounding boxes), this totals up to (26684) which are unique patient records in comparison to (30277) as mentioned earlier. As we noticed earlier that we have (20672) null records in our train\_labels dataset, we decided to define a function around those values. What we notice is that if we do not take care of these values and simply drop the same, we would be losing about (68.38%) of valuable information which will affect our overall model accuracy.

Through our visualization process of the data, we have built a pie chart to showcase the different class values present within the class\_info dataset. As we notice patients with “Lung Opacity” constitute about (31.6%) of the data which fall under Target class 1, whereas patients with “No Lung Opacity / Not Normal constitute about (39.1%) of the data, while patients who are “Normal” constitute about (29.3%) of the data. From this we can gauge that though there are two target classes (Normal, No Lung Opacity / Not Normal & Lung Opacity) we have visually displayed the data into three to showcase what percentage fall under each category. Reason to have done that is patients falling under "No Lung Opacity / Not Normal" could either mean they have no trace of the infection or they do, is why they are borderline cases.

As class\_info & train\_labels datasets match in terms of the number of records present, we have decided to merge them on the “patientId” column. On merging we observe that we now have (37629) records & 7 columns. This means we now have additional data present for which we need to analyze whether these are duplicate values, or are they bounding box coordinates highlighting those certain patients do have more than 1 box showcasing their infected areas, hence we need to tackle this in a manner where we do not have excess information causing overfitting issues during our model building activities. Visualizing via histograms we have an understanding of the density each parameter (‘x’, ‘y’, ‘width’, ‘height’) has with respect to Target outcome 1, where patients are suffering from “Lung Opacity”. Taking into consideration the skewness factor we observe ('x') is a bi-modal distribution, ('y') is right skewed which means that mode is at its heights away from the mean and the median, ('width') seems to form a normal distribution with no skewness & ('height') also seems to be right skewed, which states mode is highest in comparison to mean and median.

We have now defined the path in our drive to load the training, test images dicom datasets. We can observe that the training images dataset has (26684) images present within it, whereas the test images dataset has (3000) images present. On checking the number of bounding boxes present for each patient after merging the datasets as mentioned above, we observe (23286) patients i.e, (87%) of patients have one bounding box, (3266) patients i.e (12%) have 4 bounding boxes & (132) patients i.e (1%) have more than 4 bounding boxes.

From our metadata findings we have selected certain parameters like (ID, Modality, Age, Sex, Target and Class) so that we get a basic gist of the patient we are referring to. We have incorporated them as image titles, by visualizing train images from the dataset for Target class 0 & 1 where we have shown bounding boxes highlighting the area of those suffering from “Lung Opacity”. Those under the category of “Not Normal / No Lung Opacity, Normal we have visualized them too inorder to decipher whether they actually are clear of the infection or could fall under the infected category.

Dealing with missing values we have used the IQR technique where, the number of patients having bounding box heights treated as outliers 20, the number of patients having bounding box width treated as outliers is 81 & the number of patients having bounding box y co-ordinate treated as outliers is 15. We cannot change the width, height or y coordinates directly, so we will observe the output of some of these and check if the bounding boxes are not properly defined, we would need to remove them if required.

Inorder to treat the outliers & null values present we have used the KNNImputer method to its 3 closest neighbors’. Thereafter as per our new dataset formed, we have (30277) records and 7 columns. We have then gone ahead to resize images to 128x128x3, for which we have written a code for image augmentation. This will then process augmented images within, during our training process which will pass through an image augmented batch generator. With this we built a code for IoU inorder to showcase during our final prediction analysis, the intersection over union of our Predicted Target in comparison to the Real Target via bounding boxes.

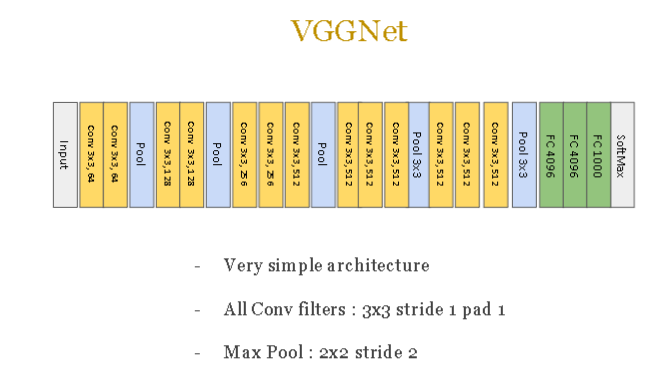
**Summary of Model Building:**

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* 1. **VGGNET Architecture**

The model is based on the layers similar to VGGNet architecture

Model architecture is as shown below:



The idea behind using this is that the architecture is very simple and instead of adding random convolution layers we had used the tested model which may probably give better results.

**INPUT:**

* The Input for our model will be an image array of 128x128x3 which is the input on which VGG architecture was built, we can use different sizes as well during model tuning.

**Output:**

* The Output of the model in the above diagram shows a dense layer of 1000 neurons, but this will not be required for our model.
* Our model must have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

Model: "sequential"

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Layer (type) Output Shape Param #

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batch\_normalization (BatchNo (None, 128, 128, 3) 12

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conv2d (Conv2D) (None, 128, 128, 64) 1792

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batch\_normalization\_1 (Batch (None, 128, 128, 64) 256

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conv2d\_1 (Conv2D) (None, 128, 128, 64) 36928

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max\_pooling2d (MaxPooling2D) (None, 64, 64, 64) 0

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batch\_normalization\_2 (Batch (None, 64, 64, 64) 256

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conv2d\_2 (Conv2D) (None, 64, 64, 128) 73856

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batch\_normalization\_3 (Batch (None, 64, 64, 128) 512

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conv2d\_3 (Conv2D) (None, 64, 64, 128) 147584

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max\_pooling2d\_1 (MaxPooling2 (None, 32, 32, 128) 0

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batch\_normalization\_4 (Batch (None, 32, 32, 128) 512

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conv2d\_4 (Conv2D) (None, 32, 32, 256) 295168

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batch\_normalization\_5 (Batch (None, 32, 32, 256) 1024

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conv2d\_5 (Conv2D) (None, 32, 32, 256) 590080

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batch\_normalization\_6 (Batch (None, 32, 32, 256) 1024

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conv2d\_6 (Conv2D) (None, 32, 32, 256) 590080

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max\_pooling2d\_2 (MaxPooling2 (None, 16, 16, 256) 0

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batch\_normalization\_7 (Batch (None, 16, 16, 256) 1024

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conv2d\_7 (Conv2D) (None, 16, 16, 512) 1180160

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batch\_normalization\_8 (Batch (None, 16, 16, 512) 2048

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conv2d\_8 (Conv2D) (None, 16, 16, 512) 2359808

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batch\_normalization\_9 (Batch (None, 16, 16, 512) 2048

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conv2d\_9 (Conv2D) (None, 16, 16, 512) 2359808

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max\_pooling2d\_3 (MaxPooling2 (None, 7, 7, 512) 0

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batch\_normalization\_10 (Batc (None, 7, 7, 512) 2048

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conv2d\_10 (Conv2D) (None, 7, 7, 512) 2359808

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batch\_normalization\_11 (Batc (None, 7, 7, 512) 2048

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conv2d\_11 (Conv2D) (None, 7, 7, 512) 2359808

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batch\_normalization\_12 (Batc (None, 7, 7, 512) 2048

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conv2d\_12 (Conv2D) (None, 7, 7, 512) 2359808

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max\_pooling2d\_4 (MaxPooling2 (None, 3, 3, 512) 0

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flatten (Flatten) (None, 4608) 0

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dense (Dense) (None, 4096) 18878464

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dropout (Dropout) (None, 4096) 0

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dense\_1 (Dense) (None, 4096) 16781312

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dropout\_1 (Dropout) (None, 4096) 0

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Total params: 50,389,324

Trainable params: 50,381,894

Non-trainable params: 7,430

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**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 60 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 60 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.24, Validation Iou => 0.31
  + Train\_accuracy => % 92.68, Validation accuracy => 82.19%

**Prediction:**

We did not capture it at the moment as the accuracy is low.

**Note:**

As each image can have multiple bounding boxes in reality, but as the first step our model will be detecting only 1 bounding box. In the later stage we will use different methods by incorporating algorithms like selective search and the Roi pooling layer which will support the model to detect all the possible bounding boxes.

* 1. **Simple CNN Model Building using (Adam Optimizer)**

We have future gone ahead to train a simple CNN model against the VGGNET model we trained prior, inorder to check if there a vast difference in results.

**INPUT:**

* The Input for our model will be an image array of 128x128x3 which is the input on which the initial architecture was built, we can use different sizes as well during model tuning.

**Output:**

* Our model will have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

Model: "sequential\_1"

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Layer (type) Output Shape Param #

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conv2d\_13 (Conv2D) (None, 126, 126, 32) 896

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conv2d\_14 (Conv2D) (None, 122, 122, 64) 51264

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max\_pooling2d\_5 (MaxPooling2 (None, 61, 61, 64) 0

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dropout\_2 (Dropout) (None, 61, 61, 64) 0

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conv2d\_15 (Conv2D) (None, 57, 57, 64) 102464

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max\_pooling2d\_6 (MaxPooling2 (None, 28, 28, 64) 0

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dropout\_3 (Dropout) (None, 28, 28, 64) 0

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conv2d\_16 (Conv2D) (None, 24, 24, 128) 204928

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max\_pooling2d\_7 (MaxPooling2 (None, 12, 12, 128) 0

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dropout\_4 (Dropout) (None, 12, 12, 128) 0

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flatten\_1 (Flatten) (None, 18432) 0

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dense\_2 (Dense) (None, 64) 1179712

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dropout\_5 (Dropout) (None, 64) 0

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dense\_3 (Dense) (None, 100) 6500

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batch\_normalization\_13 (Batc (None, 100) 400

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activation (Activation) (None, 100) 0

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dense\_4 (Dense) (None, 1) 101

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activation\_1 (Activation) (None, 1) 0

=================================================================

Total params: 1,546,265

Trainable params: 1,546,065

Non-trainable params: 200

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**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Optimizer:**

* We have used the “adam” optimizer function for the initial model.

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 50 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 50 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.01, Validation Iou => 0.6
  + Train\_accuracy => 83.32% , Validation accuracy => 80.96%
  1. **UNET Model Building**

**Summary of Model Building:**

==========================

What is Unet Architecture?

UNet is a convolutional neural network architecture that expanded with few changes in the CNN architecture. It was invented to deal with biomedical images where the target is not only to classify whether there is an infection or not but also to identify the area of infection.

The Image shows a typical architecture of the UNET model.

The advantage of this architecture is

1. Input image size and output size of the model will be same
2. Reduced number of computations

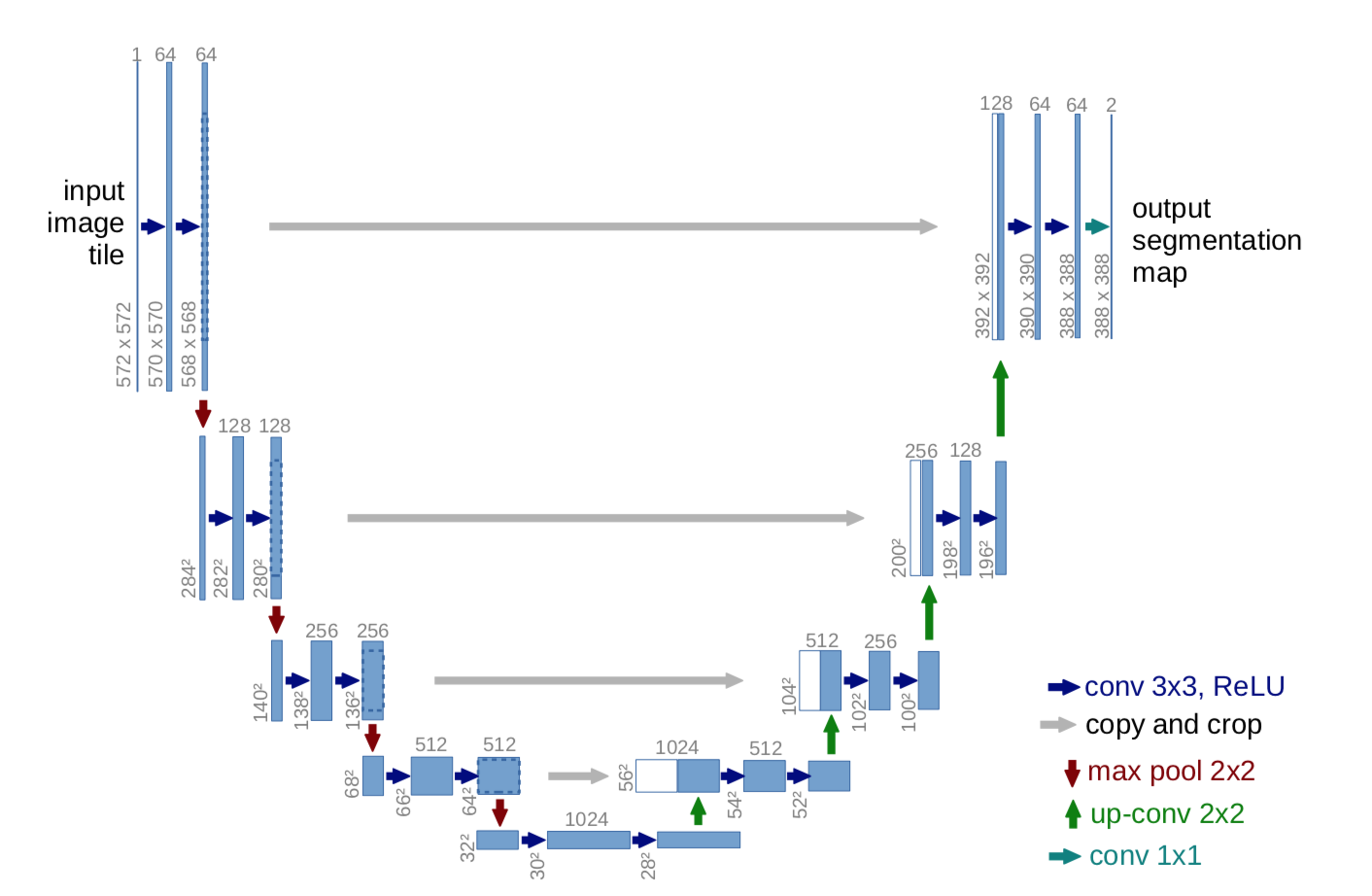
Basically the model follows a “U” shaped pattern where the input on the left hand side is first downsampled by decreasing the length and width of the image and increasing the depth making it a low resolution image, then upsample it to bring back the image to the same dimensions as input.

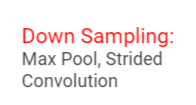
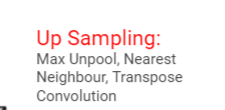
For our model the input size will be 128x128x3

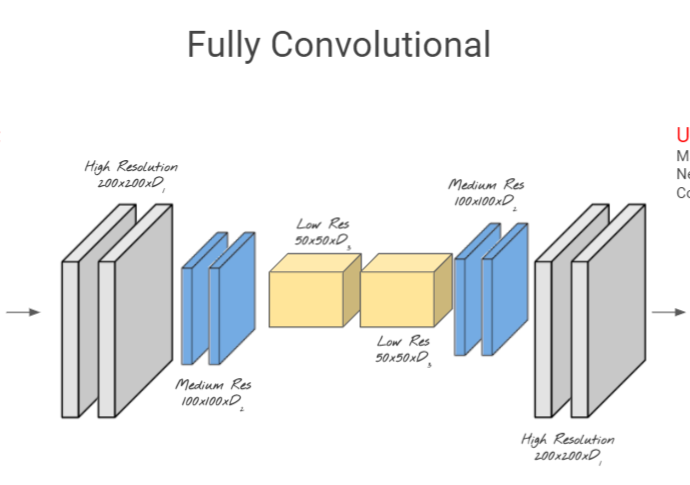
We downsample it till 8x8x64 using keras api conv2d and maxpooling2d

Upsample till 128x128x3

The upsample is done using the special keras api conv2d\_transpose





**INPUT:**

* The Input for our model will be an image array of 128x128x3

**Output:**

* The Output of the model in the above diagram shows a dense layer of 1000 neurons, but this will not be required for our model.
* Our model must have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

**From the summary we can see it has only 2 million weights compared to 50 million weights in VGG model**

Model: "model"

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Layer (type) Output Shape Param # Connected to

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input\_img (InputLayer) [(None, 128, 128, 3) 0

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conv2d (Conv2D) (None, 128, 128, 16) 448 input\_img[0][0]

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batch\_normalization (BatchNorma (None, 128, 128, 16) 64 conv2d[0][0]

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activation (Activation) (None, 128, 128, 16) 0 batch\_normalization[0][0]

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conv2d\_1 (Conv2D) (None, 128, 128, 16) 2320 activation[0][0]

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batch\_normalization\_1 (BatchNor (None, 128, 128, 16) 64 conv2d\_1[0][0]

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activation\_1 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_1[0][0]

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max\_pooling2d (MaxPooling2D) (None, 64, 64, 16) 0 activation\_1[0][0]

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dropout (Dropout) (None, 64, 64, 16) 0 max\_pooling2d[0][0]

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conv2d\_2 (Conv2D) (None, 64, 64, 32) 4640 dropout[0][0]

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batch\_normalization\_2 (BatchNor (None, 64, 64, 32) 128 conv2d\_2[0][0]

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activation\_2 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_2[0][0]

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conv2d\_3 (Conv2D) (None, 64, 64, 32) 9248 activation\_2[0][0]

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batch\_normalization\_3 (BatchNor (None, 64, 64, 32) 128 conv2d\_3[0][0]

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activation\_3 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_3[0][0]

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max\_pooling2d\_1 (MaxPooling2D) (None, 32, 32, 32) 0 activation\_3[0][0]

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dropout\_1 (Dropout) (None, 32, 32, 32) 0 max\_pooling2d\_1[0][0]

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conv2d\_4 (Conv2D) (None, 32, 32, 64) 18496 dropout\_1[0][0]

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batch\_normalization\_4 (BatchNor (None, 32, 32, 64) 256 conv2d\_4[0][0]

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activation\_4 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_4[0][0]

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conv2d\_5 (Conv2D) (None, 32, 32, 64) 36928 activation\_4[0][0]

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batch\_normalization\_5 (BatchNor (None, 32, 32, 64) 256 conv2d\_5[0][0]

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activation\_5 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_5[0][0]

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max\_pooling2d\_2 (MaxPooling2D) (None, 16, 16, 64) 0 activation\_5[0][0]

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dropout\_2 (Dropout) (None, 16, 16, 64) 0 max\_pooling2d\_2[0][0]

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conv2d\_6 (Conv2D) (None, 16, 16, 128) 73856 dropout\_2[0][0]

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batch\_normalization\_6 (BatchNor (None, 16, 16, 128) 512 conv2d\_6[0][0]

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activation\_6 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_6[0][0]

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conv2d\_7 (Conv2D) (None, 16, 16, 128) 147584 activation\_6[0][0]

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batch\_normalization\_7 (BatchNor (None, 16, 16, 128) 512 conv2d\_7[0][0]

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activation\_7 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_7[0][0]

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max\_pooling2d\_3 (MaxPooling2D) (None, 8, 8, 128) 0 activation\_7[0][0]

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dropout\_3 (Dropout) (None, 8, 8, 128) 0 max\_pooling2d\_3[0][0]

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conv2d\_8 (Conv2D) (None, 8, 8, 256) 295168 dropout\_3[0][0]

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batch\_normalization\_8 (BatchNor (None, 8, 8, 256) 1024 conv2d\_8[0][0]

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activation\_8 (Activation) (None, 8, 8, 256) 0 batch\_normalization\_8[0][0]

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conv2d\_9 (Conv2D) (None, 8, 8, 256) 590080 activation\_8[0][0]

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batch\_normalization\_9 (BatchNor (None, 8, 8, 256) 1024 conv2d\_9[0][0]

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activation\_9 (Activation) (None, 8, 8, 256) 0 batch\_normalization\_9[0][0]

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conv2d\_transpose (Conv2DTranspo (None, 16, 16, 128) 295040 activation\_9[0][0]

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concatenate (Concatenate) (None, 16, 16, 256) 0 conv2d\_transpose[0][0]

activation\_7[0][0]

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dropout\_4 (Dropout) (None, 16, 16, 256) 0 concatenate[0][0]

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conv2d\_10 (Conv2D) (None, 16, 16, 128) 295040 dropout\_4[0][0]

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batch\_normalization\_10 (BatchNo (None, 16, 16, 128) 512 conv2d\_10[0][0]

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activation\_10 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_10[0][0]

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conv2d\_11 (Conv2D) (None, 16, 16, 128) 147584 activation\_10[0][0]

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batch\_normalization\_11 (BatchNo (None, 16, 16, 128) 512 conv2d\_11[0][0]

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activation\_11 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_11[0][0]

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conv2d\_transpose\_1 (Conv2DTrans (None, 32, 32, 64) 73792 activation\_11[0][0]

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concatenate\_1 (Concatenate) (None, 32, 32, 128) 0 conv2d\_transpose\_1[0][0]

activation\_5[0][0]

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dropout\_5 (Dropout) (None, 32, 32, 128) 0 concatenate\_1[0][0]

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conv2d\_12 (Conv2D) (None, 32, 32, 64) 73792 dropout\_5[0][0]

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batch\_normalization\_12 (BatchNo (None, 32, 32, 64) 256 conv2d\_12[0][0]

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activation\_12 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_12[0][0]

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conv2d\_13 (Conv2D) (None, 32, 32, 64) 36928 activation\_12[0][0]

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batch\_normalization\_13 (BatchNo (None, 32, 32, 64) 256 conv2d\_13[0][0]

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activation\_13 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_13[0][0]

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conv2d\_transpose\_2 (Conv2DTrans (None, 64, 64, 32) 18464 activation\_13[0][0]

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concatenate\_2 (Concatenate) (None, 64, 64, 64) 0 conv2d\_transpose\_2[0][0]

activation\_3[0][0]

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dropout\_6 (Dropout) (None, 64, 64, 64) 0 concatenate\_2[0][0]

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conv2d\_14 (Conv2D) (None, 64, 64, 32) 18464 dropout\_6[0][0]

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batch\_normalization\_14 (BatchNo (None, 64, 64, 32) 128 conv2d\_14[0][0]

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activation\_14 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_14[0][0]

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conv2d\_15 (Conv2D) (None, 64, 64, 32) 9248 activation\_14[0][0]

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batch\_normalization\_15 (BatchNo (None, 64, 64, 32) 128 conv2d\_15[0][0]

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activation\_15 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_15[0][0]

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conv2d\_transpose\_3 (Conv2DTrans (None, 128, 128, 16) 4624 activation\_15[0][0]

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concatenate\_3 (Concatenate) (None, 128, 128, 32) 0 conv2d\_transpose\_3[0][0]

activation\_1[0][0]

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dropout\_7 (Dropout) (None, 128, 128, 32) 0 concatenate\_3[0][0]

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conv2d\_16 (Conv2D) (None, 128, 128, 16) 4624 dropout\_7[0][0]

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batch\_normalization\_16 (BatchNo (None, 128, 128, 16) 64 conv2d\_16[0][0]

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activation\_16 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_16[0][0]

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conv2d\_17 (Conv2D) (None, 128, 128, 16) 2320 activation\_16[0][0]

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batch\_normalization\_17 (BatchNo (None, 128, 128, 16) 64 conv2d\_17[0][0]

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activation\_17 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_17[0][0]

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global\_average\_pooling2d (Globa (None, 16) 0 activation\_17[0][0]

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class\_op (Dense) (None, 1) 17 global\_average\_pooling2d[0][0]

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reg\_op (Dense) (None, 4) 68 global\_average\_pooling2d[0][0]

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Total params: 2,164,661

Trainable params: 2,161,717

Non-trainable params: 2,944

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**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 50 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 50 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.25, Validation Iou => 0.36
  + Train\_accuracy => 84.58% , Validation accuracy => 82.61%
  1. **Tensor flow Object Detection API Building**

We further went on build and check the accuracy we are receiving in terms of bounding box predicting using the tensorflow object detection api. We did receive a confidence threshold of (0.72). But we wanted to strive further and see if we can go to better levels.

* 1. **Hyper Parameter Tunning (Simple CNN using RMSProp Optimizer)**

We have future gone ahead to train a simple CNN model using RMSProp, inorder to check if there a vast difference in results.

**INPUT:**

* The Input for our model will be an image array of 128x128x3 which is the input on which the initial architecture was built, we can use different sizes as well during model tuning.

**Output:**

* Our model will have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

Model: "sequential"

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Layer (type) Output Shape Param #

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conv2d\_18 (Conv2D) (None, 126, 126, 32) 896

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conv2d\_19 (Conv2D) (None, 122, 122, 64) 51264

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max\_pooling2d\_4 (MaxPooling2 (None, 61, 61, 64) 0

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dropout\_8 (Dropout) (None, 61, 61, 64) 0

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conv2d\_20 (Conv2D) (None, 57, 57, 64) 102464

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max\_pooling2d\_5 (MaxPooling2 (None, 28, 28, 64) 0

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dropout\_9 (Dropout) (None, 28, 28, 64) 0

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conv2d\_21 (Conv2D) (None, 24, 24, 128) 204928

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max\_pooling2d\_6 (MaxPooling2 (None, 12, 12, 128) 0

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dropout\_10 (Dropout) (None, 12, 12, 128) 0

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flatten (Flatten) (None, 18432) 0

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dense (Dense) (None, 64) 1179712

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dense\_1 (Dense) (None, 100) 6500

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batch\_normalization\_18 (Batc (None, 100) 400

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activation\_18 (Activation) (None, 100) 0

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dense\_2 (Dense) (None, 1) 101

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activation\_19 (Activation) (None, 1) 0

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Total params: 1,546,265

Trainable params: 1,546,065

Non-trainable params: 200

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**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Optimizer:**

* We have used the “RMSProp” optimizer function for the initial model.

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (patience as 0.01) and (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 50 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 50 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.07, Validation Iou => 0.06
  + Train\_accuracy => 84.13% , Validation accuracy => 81.45%
  1. **Hyper Parameter Tunning (Simple CNN using SGD Optimizer)**

We have future gone ahead to train a simple CNN model using SGD optimizer, inorder to check if there a vast difference in results.

**INPUT:**

* The Input for our model will be an image array of 128x128x3 which is the input on which the initial architecture was built, we can use different sizes as well during model tuning.

**Output:**

* Our model will have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

Model: "sequential\_1"

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Layer (type) Output Shape Param #

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conv2d\_22 (Conv2D) (None, 126, 126, 32) 896

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conv2d\_23 (Conv2D) (None, 122, 122, 64) 51264

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max\_pooling2d\_7 (MaxPooling2 (None, 61, 61, 64) 0

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dropout\_12 (Dropout) (None, 61, 61, 64) 0

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conv2d\_24 (Conv2D) (None, 57, 57, 64) 102464

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max\_pooling2d\_8 (MaxPooling2 (None, 28, 28, 64) 0

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dropout\_13 (Dropout) (None, 28, 28, 64) 0

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conv2d\_25 (Conv2D) (None, 24, 24, 128) 204928

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max\_pooling2d\_9 (MaxPooling2 (None, 12, 12, 128) 0

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dropout\_14 (Dropout) (None, 12, 12, 128) 0

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flatten\_1 (Flatten) (None, 18432) 0

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dense\_3 (Dense) (None, 64) 1179712

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dropout\_15 (Dropout) (None, 64) 0

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dense\_4 (Dense) (None, 100) 6500

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batch\_normalization\_19 (Batc (None, 100) 400

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activation\_20 (Activation) (None, 100) 0

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dense\_5 (Dense) (None, 1) 101

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activation\_21 (Activation) (None, 1) 0

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Total params: 1,546,265

Trainable params: 1,546,065

Non-trainable params: 200

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**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Optimizer:**

* We have used the “SGD” optimizer function for the initial model.

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (patience as 0.01) and (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 50 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 50 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.07, Validation Iou => 0.06
  + Train\_accuracy => 78.85% , Validation accuracy => 77.70%
  1. **VGG model (Using Leaky Relu)**

We have future gone ahead to train a VGG model using leaky relu, inorder to check if there a vast difference in results.

**INPUT:**

* The Input for our model will be an image array of 128x128x3 which is the input on which the initial architecture was built, we can use different sizes as well during model tuning.

**Output:**

* Our model will have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

Model: "model"

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Layer (type) Output Shape Param # Connected to

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batch\_normalization\_input (Inpu [(None, 128, 128, 3) 0

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batch\_normalization (BatchNorma (None, 128, 128, 3) 12 batch\_normalization\_input[0][0]

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conv2d (Conv2D) (None, 128, 128, 64) 1792 batch\_normalization[0][0]

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leaky\_re\_lu (LeakyReLU) (None, 128, 128, 64) 0 conv2d[0][0]

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batch\_normalization\_1 (BatchNor (None, 128, 128, 64) 256 leaky\_re\_lu[0][0]

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conv2d\_1 (Conv2D) (None, 128, 128, 64) 36928 batch\_normalization\_1[0][0]

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leaky\_re\_lu\_1 (LeakyReLU) (None, 128, 128, 64) 0 conv2d\_1[0][0]

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max\_pooling2d (MaxPooling2D) (None, 64, 64, 64) 0 leaky\_re\_lu\_1[0][0]

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batch\_normalization\_2 (BatchNor (None, 64, 64, 64) 256 max\_pooling2d[0][0]

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conv2d\_2 (Conv2D) (None, 64, 64, 128) 73856 batch\_normalization\_2[0][0]

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leaky\_re\_lu\_2 (LeakyReLU) (None, 64, 64, 128) 0 conv2d\_2[0][0]

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batch\_normalization\_3 (BatchNor (None, 64, 64, 128) 512 leaky\_re\_lu\_2[0][0]

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conv2d\_3 (Conv2D) (None, 64, 64, 128) 147584 batch\_normalization\_3[0][0]

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leaky\_re\_lu\_3 (LeakyReLU) (None, 64, 64, 128) 0 conv2d\_3[0][0]

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max\_pooling2d\_1 (MaxPooling2D) (None, 32, 32, 128) 0 leaky\_re\_lu\_3[0][0]

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batch\_normalization\_4 (BatchNor (None, 32, 32, 128) 512 max\_pooling2d\_1[0][0]

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conv2d\_4 (Conv2D) (None, 32, 32, 256) 295168 batch\_normalization\_4[0][0]

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leaky\_re\_lu\_4 (LeakyReLU) (None, 32, 32, 256) 0 conv2d\_4[0][0]

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batch\_normalization\_5 (BatchNor (None, 32, 32, 256) 1024 leaky\_re\_lu\_4[0][0]

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conv2d\_5 (Conv2D) (None, 32, 32, 256) 590080 batch\_normalization\_5[0][0]

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leaky\_re\_lu\_5 (LeakyReLU) (None, 32, 32, 256) 0 conv2d\_5[0][0]

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batch\_normalization\_6 (BatchNor (None, 32, 32, 256) 1024 leaky\_re\_lu\_5[0][0]

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conv2d\_6 (Conv2D) (None, 32, 32, 256) 590080 batch\_normalization\_6[0][0]

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leaky\_re\_lu\_6 (LeakyReLU) (None, 32, 32, 256) 0 conv2d\_6[0][0]

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max\_pooling2d\_2 (MaxPooling2D) (None, 16, 16, 256) 0 leaky\_re\_lu\_6[0][0]

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batch\_normalization\_7 (BatchNor (None, 16, 16, 256) 1024 max\_pooling2d\_2[0][0]

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conv2d\_7 (Conv2D) (None, 16, 16, 512) 1180160 batch\_normalization\_7[0][0]

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leaky\_re\_lu\_7 (LeakyReLU) (None, 16, 16, 512) 0 conv2d\_7[0][0]

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batch\_normalization\_8 (BatchNor (None, 16, 16, 512) 2048 leaky\_re\_lu\_7[0][0]

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conv2d\_8 (Conv2D) (None, 16, 16, 512) 2359808 batch\_normalization\_8[0][0]

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leaky\_re\_lu\_8 (LeakyReLU) (None, 16, 16, 512) 0 conv2d\_8[0][0]

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batch\_normalization\_9 (BatchNor (None, 16, 16, 512) 2048 leaky\_re\_lu\_8[0][0]

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conv2d\_9 (Conv2D) (None, 16, 16, 512) 2359808 batch\_normalization\_9[0][0]

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leaky\_re\_lu\_9 (LeakyReLU) (None, 16, 16, 512) 0 conv2d\_9[0][0]

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max\_pooling2d\_3 (MaxPooling2D) (None, 7, 7, 512) 0 leaky\_re\_lu\_9[0][0]

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batch\_normalization\_10 (BatchNo (None, 7, 7, 512) 2048 max\_pooling2d\_3[0][0]

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conv2d\_10 (Conv2D) (None, 7, 7, 512) 2359808 batch\_normalization\_10[0][0]

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leaky\_re\_lu\_10 (LeakyReLU) (None, 7, 7, 512) 0 conv2d\_10[0][0]

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batch\_normalization\_11 (BatchNo (None, 7, 7, 512) 2048 leaky\_re\_lu\_10[0][0]

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conv2d\_11 (Conv2D) (None, 7, 7, 512) 2359808 batch\_normalization\_11[0][0]

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leaky\_re\_lu\_11 (LeakyReLU) (None, 7, 7, 512) 0 conv2d\_11[0][0]

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batch\_normalization\_12 (BatchNo (None, 7, 7, 512) 2048 leaky\_re\_lu\_11[0][0]

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conv2d\_12 (Conv2D) (None, 7, 7, 512) 2359808 batch\_normalization\_12[0][0]

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leaky\_re\_lu\_12 (LeakyReLU) (None, 7, 7, 512) 0 conv2d\_12[0][0]

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max\_pooling2d\_4 (MaxPooling2D) (None, 3, 3, 512) 0 leaky\_re\_lu\_12[0][0]

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flatten (Flatten) (None, 4608) 0 max\_pooling2d\_4[0][0]

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dense (Dense) (None, 4096) 18878464 flatten[0][0]

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leaky\_re\_lu\_13 (LeakyReLU) (None, 4096) 0 dense[0][0]

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dropout (Dropout) (None, 4096) 0 leaky\_re\_lu\_13[0][0]

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dense\_1 (Dense) (None, 4096) 16781312 dropout[0][0]

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leaky\_re\_lu\_14 (LeakyReLU) (None, 4096) 0 dense\_1[0][0]

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dropout\_1 (Dropout) (None, 4096) 0 leaky\_re\_lu\_14[0][0]

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class\_op (Dense) (None, 1) 4097 dropout\_1[0][0]

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reg\_op (Dense) (None, 4) 16388 dropout\_1[0][0]

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Total params: 50,409,809

Trainable params: 50,402,379

Non-trainable params: 7,430

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**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Activation:**

* We have used “Leaky Relu” as the activation function

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 20 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 20 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => nan, Validation Iou => nan
  + Train\_accuracy => 78.85% , Validation accuracy => 76.23%
  1. **VGG model removed dense layer at the end to reduce weights**

We have future gone ahead to train a VGG model removed dense layer at the end to reduce weights, inorder to check if there a vast difference in results.

**INPUT:**

* The Input for our model will be an image array of 128x128x3 which is the input on which the initial architecture was built, we can use different sizes as well during model tuning.

**Output:**

* Our model will have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

Model: "model"

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Layer (type) Output Shape Param # Connected to

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batch\_normalization\_input (Inpu [(None, 128, 128, 3) 0

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batch\_normalization (BatchNorma (None, 128, 128, 3) 12 batch\_normalization\_input[0][0]

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conv2d (Conv2D) (None, 128, 128, 64) 1792 batch\_normalization[0][0]

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conv2d\_1 (Conv2D) (None, 128, 128, 64) 36928 conv2d[0][0]

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max\_pooling2d (MaxPooling2D) (None, 64, 64, 64) 0 conv2d\_1[0][0]

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conv2d\_2 (Conv2D) (None, 64, 64, 128) 73856 max\_pooling2d[0][0]

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conv2d\_3 (Conv2D) (None, 64, 64, 128) 147584 conv2d\_2[0][0]

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max\_pooling2d\_1 (MaxPooling2D) (None, 32, 32, 128) 0 conv2d\_3[0][0]

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conv2d\_4 (Conv2D) (None, 32, 32, 256) 295168 max\_pooling2d\_1[0][0]

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conv2d\_5 (Conv2D) (None, 32, 32, 256) 590080 conv2d\_4[0][0]

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conv2d\_6 (Conv2D) (None, 32, 32, 256) 590080 conv2d\_5[0][0]

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max\_pooling2d\_2 (MaxPooling2D) (None, 16, 16, 256) 0 conv2d\_6[0][0]

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conv2d\_7 (Conv2D) (None, 16, 16, 512) 1180160 max\_pooling2d\_2[0][0]

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conv2d\_8 (Conv2D) (None, 16, 16, 512) 2359808 conv2d\_7[0][0]

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conv2d\_9 (Conv2D) (None, 16, 16, 512) 2359808 conv2d\_8[0][0]

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max\_pooling2d\_3 (MaxPooling2D) (None, 7, 7, 512) 0 conv2d\_9[0][0]

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conv2d\_10 (Conv2D) (None, 7, 7, 512) 2359808 max\_pooling2d\_3[0][0]

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conv2d\_11 (Conv2D) (None, 7, 7, 512) 2359808 conv2d\_10[0][0]

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conv2d\_12 (Conv2D) (None, 7, 7, 512) 2359808 conv2d\_11[0][0]

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max\_pooling2d\_4 (MaxPooling2D) (None, 3, 3, 512) 0 conv2d\_12[0][0]

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flatten (Flatten) (None, 4608) 0 max\_pooling2d\_4[0][0]

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class\_op (Dense) (None, 1) 4609 flatten[0][0]

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reg\_op (Dense) (None, 4) 18436 flatten[0][0]

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Total params: 14,737,745

Trainable params: 14,737,739

Non-trainable params: 6

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**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 10 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 10 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.07, Validation Iou => 0.05
  + Train\_accuracy => 69.45% , Validation accuracy => 54.50%
  1. **Unet model with additional dense layers**

**INPUT:**

* The Input for our model will be an image array of 128x128x3

**Output:**

* The Output of the model in the above diagram shows a dense layer of 1000 neurons, but this will not be required for our model.
* Our model must have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

Model: "model"

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Layer (type) Output Shape Param # Connected to

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input\_img (InputLayer) [(None, 128, 128, 3) 0

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conv2d (Conv2D) (None, 128, 128, 16) 448 input\_img[0][0]

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batch\_normalization (BatchNorma (None, 128, 128, 16) 64 conv2d[0][0]

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activation (Activation) (None, 128, 128, 16) 0 batch\_normalization[0][0]

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conv2d\_1 (Conv2D) (None, 128, 128, 16) 2320 activation[0][0]

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batch\_normalization\_1 (BatchNor (None, 128, 128, 16) 64 conv2d\_1[0][0]

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activation\_1 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_1[0][0]

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max\_pooling2d (MaxPooling2D) (None, 64, 64, 16) 0 activation\_1[0][0]

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dropout (Dropout) (None, 64, 64, 16) 0 max\_pooling2d[0][0]

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conv2d\_2 (Conv2D) (None, 64, 64, 32) 4640 dropout[0][0]

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batch\_normalization\_2 (BatchNor (None, 64, 64, 32) 128 conv2d\_2[0][0]

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activation\_2 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_2[0][0]

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conv2d\_3 (Conv2D) (None, 64, 64, 32) 9248 activation\_2[0][0]

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batch\_normalization\_3 (BatchNor (None, 64, 64, 32) 128 conv2d\_3[0][0]

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activation\_3 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_3[0][0]

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max\_pooling2d\_1 (MaxPooling2D) (None, 32, 32, 32) 0 activation\_3[0][0]

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dropout\_1 (Dropout) (None, 32, 32, 32) 0 max\_pooling2d\_1[0][0]

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conv2d\_4 (Conv2D) (None, 32, 32, 64) 18496 dropout\_1[0][0]

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batch\_normalization\_4 (BatchNor (None, 32, 32, 64) 256 conv2d\_4[0][0]

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activation\_4 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_4[0][0]

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conv2d\_5 (Conv2D) (None, 32, 32, 64) 36928 activation\_4[0][0]

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batch\_normalization\_5 (BatchNor (None, 32, 32, 64) 256 conv2d\_5[0][0]

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activation\_5 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_5[0][0]

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max\_pooling2d\_2 (MaxPooling2D) (None, 16, 16, 64) 0 activation\_5[0][0]

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dropout\_2 (Dropout) (None, 16, 16, 64) 0 max\_pooling2d\_2[0][0]

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conv2d\_6 (Conv2D) (None, 16, 16, 128) 73856 dropout\_2[0][0]

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batch\_normalization\_6 (BatchNor (None, 16, 16, 128) 512 conv2d\_6[0][0]

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activation\_6 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_6[0][0]

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conv2d\_7 (Conv2D) (None, 16, 16, 128) 147584 activation\_6[0][0]

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batch\_normalization\_7 (BatchNor (None, 16, 16, 128) 512 conv2d\_7[0][0]

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activation\_7 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_7[0][0]

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max\_pooling2d\_3 (MaxPooling2D) (None, 8, 8, 128) 0 activation\_7[0][0]

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dropout\_3 (Dropout) (None, 8, 8, 128) 0 max\_pooling2d\_3[0][0]

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conv2d\_8 (Conv2D) (None, 8, 8, 256) 295168 dropout\_3[0][0]

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batch\_normalization\_8 (BatchNor (None, 8, 8, 256) 1024 conv2d\_8[0][0]

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activation\_8 (Activation) (None, 8, 8, 256) 0 batch\_normalization\_8[0][0]

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conv2d\_9 (Conv2D) (None, 8, 8, 256) 590080 activation\_8[0][0]

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batch\_normalization\_9 (BatchNor (None, 8, 8, 256) 1024 conv2d\_9[0][0]

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activation\_9 (Activation) (None, 8, 8, 256) 0 batch\_normalization\_9[0][0]

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conv2d\_transpose (Conv2DTranspo (None, 16, 16, 128) 295040 activation\_9[0][0]

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concatenate (Concatenate) (None, 16, 16, 256) 0 conv2d\_transpose[0][0]

activation\_7[0][0]

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dropout\_4 (Dropout) (None, 16, 16, 256) 0 concatenate[0][0]

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conv2d\_10 (Conv2D) (None, 16, 16, 128) 295040 dropout\_4[0][0]

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batch\_normalization\_10 (BatchNo (None, 16, 16, 128) 512 conv2d\_10[0][0]

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activation\_10 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_10[0][0]

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conv2d\_11 (Conv2D) (None, 16, 16, 128) 147584 activation\_10[0][0]

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batch\_normalization\_11 (BatchNo (None, 16, 16, 128) 512 conv2d\_11[0][0]

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activation\_11 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_11[0][0]

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conv2d\_transpose\_1 (Conv2DTrans (None, 32, 32, 64) 73792 activation\_11[0][0]

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concatenate\_1 (Concatenate) (None, 32, 32, 128) 0 conv2d\_transpose\_1[0][0]

activation\_5[0][0]

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dropout\_5 (Dropout) (None, 32, 32, 128) 0 concatenate\_1[0][0]

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conv2d\_12 (Conv2D) (None, 32, 32, 64) 73792 dropout\_5[0][0]

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batch\_normalization\_12 (BatchNo (None, 32, 32, 64) 256 conv2d\_12[0][0]

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activation\_12 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_12[0][0]

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conv2d\_13 (Conv2D) (None, 32, 32, 64) 36928 activation\_12[0][0]

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batch\_normalization\_13 (BatchNo (None, 32, 32, 64) 256 conv2d\_13[0][0]

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activation\_13 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_13[0][0]

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conv2d\_transpose\_2 (Conv2DTrans (None, 64, 64, 32) 18464 activation\_13[0][0]

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concatenate\_2 (Concatenate) (None, 64, 64, 64) 0 conv2d\_transpose\_2[0][0]

activation\_3[0][0]

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dropout\_6 (Dropout) (None, 64, 64, 64) 0 concatenate\_2[0][0]

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conv2d\_14 (Conv2D) (None, 64, 64, 32) 18464 dropout\_6[0][0]

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batch\_normalization\_14 (BatchNo (None, 64, 64, 32) 128 conv2d\_14[0][0]

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activation\_14 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_14[0][0]

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conv2d\_15 (Conv2D) (None, 64, 64, 32) 9248 activation\_14[0][0]

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batch\_normalization\_15 (BatchNo (None, 64, 64, 32) 128 conv2d\_15[0][0]

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activation\_15 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_15[0][0]

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conv2d\_transpose\_3 (Conv2DTrans (None, 128, 128, 16) 4624 activation\_15[0][0]

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concatenate\_3 (Concatenate) (None, 128, 128, 32) 0 conv2d\_transpose\_3[0][0]

activation\_1[0][0]

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dropout\_7 (Dropout) (None, 128, 128, 32) 0 concatenate\_3[0][0]

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conv2d\_16 (Conv2D) (None, 128, 128, 16) 4624 dropout\_7[0][0]

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batch\_normalization\_16 (BatchNo (None, 128, 128, 16) 64 conv2d\_16[0][0]

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activation\_16 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_16[0][0]

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conv2d\_17 (Conv2D) (None, 128, 128, 16) 2320 activation\_16[0][0]

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batch\_normalization\_17 (BatchNo (None, 128, 128, 16) 64 conv2d\_17[0][0]

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activation\_17 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_17[0][0]

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global\_average\_pooling2d (Globa (None, 16) 0 activation\_17[0][0]

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flatten (Flatten) (None, 16) 0 global\_average\_pooling2d[0][0]

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dense (Dense) (None, 4096) 69632 flatten[0][0]

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dropout\_8 (Dropout) (None, 4096) 0 dense[0][0]

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dense\_1 (Dense) (None, 4096) 16781312 dropout\_8[0][0]

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dropout\_9 (Dropout) (None, 4096) 0 dense\_1[0][0]

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class\_op (Dense) (None, 1) 4097 dropout\_9[0][0]

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reg\_op (Dense) (None, 4) 16388 dropout\_9[0][0]

==================================================================================================

Total params: 19,036,005

Trainable params: 19,033,061

Non-trainable params: 2,944

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 20 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 20 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.07, Validation Iou => 0.06
  + Train\_accuracy => 82.34% , Validation accuracy => 81.95%
  1. **Transfer learning ResNet model pretrained with ImageNet data**

**Summary on Transfer learning:**

**========================**

For obtaining better results we had followed the transfer learning method where we implemented 2 models

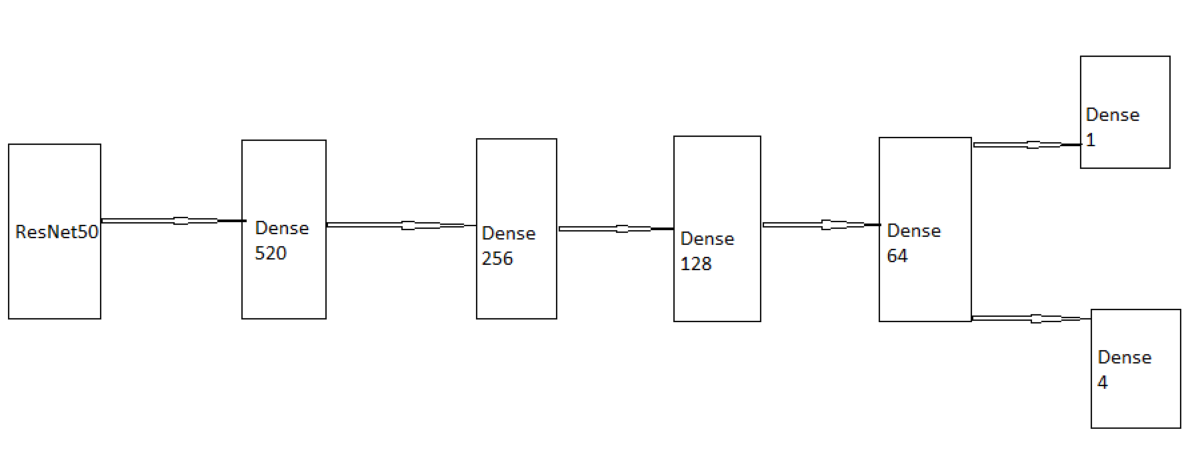
Transfer learning using Keras ResNet50 model trained with ImageNet dataset

Transfer learning using UNET model which we trained with the Pneumonia dataset

**Transfer learning using Keras ResNet50 model**

**====================================**

The model looks like below



This is basically a sequential model with a ResNet50 model pre-trained with ‘ImageNet’ Dataset on the input side and 4 Dense layers.

The ResNet model layers were freezed in order to just use the learnings(weights) from ImageNet dataset, only the trainable layers were the Dense layers connected at the output of the ResNet layer.

**INPUT:**

* The Input for our model will be an image array of 128x128x3 which is the input on which the initial architecture was built, we can use different sizes as well during model tuning.

**Output:**

* Our model will have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Model summary:**

We can see there are Totally 40 million weights

But the Trainable parameters from the ResNet model which are 23 million are freezed.

The Dense layers contribute for around 17 million weights.

Model: "model"

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Layer (type) Output Shape Param # Connected to

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resnet50\_input (InputLayer) [(None, 128, 128, 3) 0

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resnet50 (Functional) (None, 4, 4, 2048) 23587712 resnet50\_input[0][0]

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flatten (Flatten) (None, 32768) 0 resnet50[0][0]

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batch\_normalization (BatchNorma (None, 32768) 131072 flatten[0][0]

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dense (Dense) (None, 512) 16777728 batch\_normalization[0][0]

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batch\_normalization\_1 (BatchNor (None, 512) 2048 dense[0][0]

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dropout (Dropout) (None, 512) 0 batch\_normalization\_1[0][0]

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dense\_1 (Dense) (None, 256) 131328 dropout[0][0]

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batch\_normalization\_2 (BatchNor (None, 256) 1024 dense\_1[0][0]

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dropout\_1 (Dropout) (None, 256) 0 batch\_normalization\_2[0][0]

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dense\_2 (Dense) (None, 128) 32896 dropout\_1[0][0]

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batch\_normalization\_3 (BatchNor (None, 128) 512 dense\_2[0][0]

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dropout\_2 (Dropout) (None, 128) 0 batch\_normalization\_3[0][0]

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dense\_3 (Dense) (None, 64) 8256 dropout\_2[0][0]

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batch\_normalization\_4 (BatchNor (None, 64) 256 dense\_3[0][0]

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dropout\_3 (Dropout) (None, 64) 0 batch\_normalization\_4[0][0]

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activation (Activation) (None, 64) 0 dropout\_3[0][0]

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class\_op (Dense) (None, 1) 65 activation[0][0]

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reg\_op (Dense) (None, 4) 260 activation[0][0]

==================================================================================================

Total params: 40,673,157

Trainable params: 17,017,989

Non-trainable params: 23,655,168

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For Each Dense layer we have use a dropout(0.4) inorder to train better

The activation function used here is ‘relu’ except the output layer is using sigmoid.

**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set.

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (verbose as 1).

**Model Fit:**

* Model is being fit and trained on 50 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 50 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.03, Validation Iou => 0.03
  + Train\_accuracy => 83.22% , Validation accuracy => 81.35%

The model did not perform well with some amount of overfitting due to 17 million dense layer weights. Even by using dropouts the performance did not improve much.

This is because the dense layers are not able to learn the neighbouring information of our image,

Only the convolution layers learn all the information about the image better.

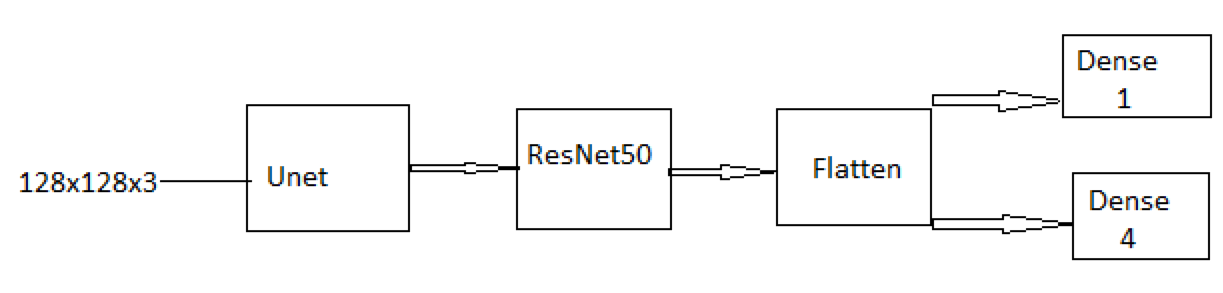
* 1. **Transfer learning ResNet model pretrained with ImageNet data**

**Summary of Transfer learning using UNET and ResNet**

**==========================================**

The model was built with Unet model trained with Pneumonia dataset at the input side

And sequentially connected to the Keras inbuilt ResNet model.



ResNet is used Mostly in order to solve a complex problem, we stack some additional layers in the Deep Neural Networks which results in improved accuracy and performance. The intuition behind adding more layers is that these layers progressively learn more complex features,

Also ResNet is a proven model which helps to tackle the vanishing gradient problem by using skip connections between l ayers, and it was proven to have very less error rate.

To implement ResNet version1 with 50 layers (ResNet 50), we simply use the function from Keras a

tf.keras.applications.ResNet50(

include\_top=True,

weights="imagenet",

input\_tensor=None,

input\_shape=None,

pooling=None,

classes=1000,

\*\*kwargs)

**Arguments:**

* **Include\_top:** whether to include the fully-connected layer at the top of the network.
* **Weights:** one of None (random initialization), ‘Imagenet’ (pre-training on ImageNet), or the path to the weights file to be loaded.
* **Input\_tensor:** optional Keras tensor (i.e. output of layers.Input()) to use as image input for the model.
* **Input\_shape:** optional shape tuple, only to be specified if include\_top is False (otherwise the input shape has to be (224, 224, 3) (with ‘channels\_last’ data format) or (3, 224, 224) (with ‘channels\_first’ data format). It should have exactly 3 inputs channels, and width and height should be no smaller than 32. E.g. (200, 200, 3) would be one valid value.
* **Pooling:** Optional pooling mode for feature extraction when include\_top is False.

None means that the output of the model will be the 4D tensor output of the last convolutional block.

avg means that global average pooling will be applied to the output of the last convolutional block, and thus the output of the model will be a 2D tensor.

max means that global max pooling will be applied.

* **Classes:** optional number of classes to classify images into, only to be specified if include\_top is True, and if no weights argument is specified.

**UNET: "model"**

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Layer (type) Output Shape Param # Connected to

==================================================================================================

input\_img (InputLayer) [(None, 128, 128, 3) 0

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conv2d (Conv2D) (None, 128, 128, 16) 448 input\_img[0][0]

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batch\_normalization (BatchNorma (None, 128, 128, 16) 64 conv2d[0][0]

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activation (Activation) (None, 128, 128, 16) 0 batch\_normalization[0][0]

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conv2d\_1 (Conv2D) (None, 128, 128, 16) 2320 activation[0][0]

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batch\_normalization\_1 (BatchNor (None, 128, 128, 16) 64 conv2d\_1[0][0]

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activation\_1 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_1[0][0]

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max\_pooling2d (MaxPooling2D) (None, 64, 64, 16) 0 activation\_1[0][0]

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dropout (Dropout) (None, 64, 64, 16) 0 max\_pooling2d[0][0]

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conv2d\_2 (Conv2D) (None, 64, 64, 32) 4640 dropout[0][0]

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batch\_normalization\_2 (BatchNor (None, 64, 64, 32) 128 conv2d\_2[0][0]

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activation\_2 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_2[0][0]

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conv2d\_3 (Conv2D) (None, 64, 64, 32) 9248 activation\_2[0][0]

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batch\_normalization\_3 (BatchNor (None, 64, 64, 32) 128 conv2d\_3[0][0]

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activation\_3 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_3[0][0]

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max\_pooling2d\_1 (MaxPooling2D) (None, 32, 32, 32) 0 activation\_3[0][0]

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dropout\_1 (Dropout) (None, 32, 32, 32) 0 max\_pooling2d\_1[0][0]

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conv2d\_4 (Conv2D) (None, 32, 32, 64) 18496 dropout\_1[0][0]

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batch\_normalization\_4 (BatchNor (None, 32, 32, 64) 256 conv2d\_4[0][0]

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activation\_4 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_4[0][0]

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conv2d\_5 (Conv2D) (None, 32, 32, 64) 36928 activation\_4[0][0]

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batch\_normalization\_5 (BatchNor (None, 32, 32, 64) 256 conv2d\_5[0][0]

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activation\_5 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_5[0][0]

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max\_pooling2d\_2 (MaxPooling2D) (None, 16, 16, 64) 0 activation\_5[0][0]

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dropout\_2 (Dropout) (None, 16, 16, 64) 0 max\_pooling2d\_2[0][0]

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conv2d\_6 (Conv2D) (None, 16, 16, 128) 73856 dropout\_2[0][0]

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batch\_normalization\_6 (BatchNor (None, 16, 16, 128) 512 conv2d\_6[0][0]

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activation\_6 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_6[0][0]

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conv2d\_7 (Conv2D) (None, 16, 16, 128) 147584 activation\_6[0][0]

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batch\_normalization\_7 (BatchNor (None, 16, 16, 128) 512 conv2d\_7[0][0]

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activation\_7 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_7[0][0]

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max\_pooling2d\_3 (MaxPooling2D) (None, 8, 8, 128) 0 activation\_7[0][0]

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dropout\_3 (Dropout) (None, 8, 8, 128) 0 max\_pooling2d\_3[0][0]

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conv2d\_8 (Conv2D) (None, 8, 8, 256) 295168 dropout\_3[0][0]

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batch\_normalization\_8 (BatchNor (None, 8, 8, 256) 1024 conv2d\_8[0][0]

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activation\_8 (Activation) (None, 8, 8, 256) 0 batch\_normalization\_8[0][0]

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conv2d\_9 (Conv2D) (None, 8, 8, 256) 590080 activation\_8[0][0]

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batch\_normalization\_9 (BatchNor (None, 8, 8, 256) 1024 conv2d\_9[0][0]

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activation\_9 (Activation) (None, 8, 8, 256) 0 batch\_normalization\_9[0][0]

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conv2d\_transpose (Conv2DTranspo (None, 16, 16, 128) 295040 activation\_9[0][0]

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concatenate (Concatenate) (None, 16, 16, 256) 0 conv2d\_transpose[0][0]

activation\_7[0][0]

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dropout\_4 (Dropout) (None, 16, 16, 256) 0 concatenate[0][0]

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conv2d\_10 (Conv2D) (None, 16, 16, 128) 295040 dropout\_4[0][0]

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batch\_normalization\_10 (BatchNo (None, 16, 16, 128) 512 conv2d\_10[0][0]

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activation\_10 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_10[0][0]

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conv2d\_11 (Conv2D) (None, 16, 16, 128) 147584 activation\_10[0][0]

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batch\_normalization\_11 (BatchNo (None, 16, 16, 128) 512 conv2d\_11[0][0]

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activation\_11 (Activation) (None, 16, 16, 128) 0 batch\_normalization\_11[0][0]

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conv2d\_transpose\_1 (Conv2DTrans (None, 32, 32, 64) 73792 activation\_11[0][0]

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concatenate\_1 (Concatenate) (None, 32, 32, 128) 0 conv2d\_transpose\_1[0][0]

activation\_5[0][0]

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dropout\_5 (Dropout) (None, 32, 32, 128) 0 concatenate\_1[0][0]

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conv2d\_12 (Conv2D) (None, 32, 32, 64) 73792 dropout\_5[0][0]

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batch\_normalization\_12 (BatchNo (None, 32, 32, 64) 256 conv2d\_12[0][0]

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activation\_12 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_12[0][0]

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conv2d\_13 (Conv2D) (None, 32, 32, 64) 36928 activation\_12[0][0]

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batch\_normalization\_13 (BatchNo (None, 32, 32, 64) 256 conv2d\_13[0][0]

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activation\_13 (Activation) (None, 32, 32, 64) 0 batch\_normalization\_13[0][0]

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conv2d\_transpose\_2 (Conv2DTrans (None, 64, 64, 32) 18464 activation\_13[0][0]

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concatenate\_2 (Concatenate) (None, 64, 64, 64) 0 conv2d\_transpose\_2[0][0]

activation\_3[0][0]

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dropout\_6 (Dropout) (None, 64, 64, 64) 0 concatenate\_2[0][0]

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conv2d\_14 (Conv2D) (None, 64, 64, 32) 18464 dropout\_6[0][0]

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batch\_normalization\_14 (BatchNo (None, 64, 64, 32) 128 conv2d\_14[0][0]

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activation\_14 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_14[0][0]

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conv2d\_15 (Conv2D) (None, 64, 64, 32) 9248 activation\_14[0][0]

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batch\_normalization\_15 (BatchNo (None, 64, 64, 32) 128 conv2d\_15[0][0]

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activation\_15 (Activation) (None, 64, 64, 32) 0 batch\_normalization\_15[0][0]

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conv2d\_transpose\_3 (Conv2DTrans (None, 128, 128, 16) 4624 activation\_15[0][0]

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concatenate\_3 (Concatenate) (None, 128, 128, 32) 0 conv2d\_transpose\_3[0][0]

activation\_1[0][0]

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dropout\_7 (Dropout) (None, 128, 128, 32) 0 concatenate\_3[0][0]

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conv2d\_16 (Conv2D) (None, 128, 128, 16) 4624 dropout\_7[0][0]

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batch\_normalization\_16 (BatchNo (None, 128, 128, 16) 64 conv2d\_16[0][0]

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activation\_16 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_16[0][0]

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conv2d\_17 (Conv2D) (None, 128, 128, 16) 2320 activation\_16[0][0]

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batch\_normalization\_17 (BatchNo (None, 128, 128, 16) 64 conv2d\_17[0][0]

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activation\_17 (Activation) (None, 128, 128, 16) 0 batch\_normalization\_17[0][0]

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global\_average\_pooling2d (Globa (None, 16) 0 activation\_17[0][0]

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class\_op (Dense) (None, 1) 17 global\_average\_pooling2d[0][0]

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reg\_op (Dense) (None, 4) 68 global\_average\_pooling2d[0][0]

==================================================================================================

Total params: 2,164,661

Trainable params: 2,161,717

Non-trainable params: 2,944

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We can see that from the summary Inorder to connect the UNET model to Resnet model

We had to remove the output layers of the Unet model which were a Flattening layer which internally connected to classification and Regression Dense layers.

After removing these layers we could not just connect the UNET model directly to the ResNet50 model input, as UNET is a functional layer and we do not have to model.add api in the functional model.

So to connect these models we had to write the below code:

from keras.models import Model

#removing the output layer from the pretrained unet model

prev\_model = keras.models.Model(UnetModel\_v1.input, UnetModel\_v1.layers[-4].output)

Unet\_transfer\_model = Sequential()

Unet\_transfer\_model.add(prev\_model)

Unet\_transfer\_model.add(tf.keras.applications.ResNet50(input\_shape= (image\_size, image\_size, 16), include\_top=False, weights=None))

Unet\_transfer\_model.add(tf.keras.layers.GlobalAveragePooling2D())

#Global average pool to reduce number of features and Flatten the output

#Classification output

label\_output = tf.keras.layers.Dense(1,

activation='sigmoid',

name='class\_op')(last\_layer)

#Regression

bbox\_output = tf.keras.layers.Dense(4,

activation='sigmoid',

name='reg\_op')(last\_layer)

Unet\_transfer\_model = tf.keras.models.Model(inputs=Unet\_transfer\_model.input, #Pre-trained model input as input layer

outputs=[label\_output,bbox\_output]) #Output layer added

We can see that it's not allowed to directly connect Unet model output to ResNet model as we cannot connect Functional and Sequential models directly.

So we had to create a sequential model , then add the Unet layers and ResNet model.

**Final model:**

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Layer (type) Output Shape Param # Connected to

==================================================================================================

model\_input (InputLayer) [(None, 128, 128, 3) 0

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model (Functional) (None, 128, 128, 16) 2164576 model\_input[0][0]

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resnet50 (Functional) (None, 4, 4, 2048) 23628480 model[0][0]

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global\_average\_pooling2d (Globa (None, 2048) 0 resnet50[0][0]

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class\_op (Dense) (None, 1) 2049 global\_average\_pooling2d[0][0]

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reg\_op (Dense) (None, 4) 8196 global\_average\_pooling2d[0][0]

==================================================================================================

Total params: 25,803,301

Trainable params: 23,585,605

Non-trainable params: 2,217,696

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We can see that he Trainable parameters of UNET Model are set to false as we have already trained them with Pneumonia detection Dataset

**UNET model has around 2 million weights compared to 25 million weights from ResNet**

**INPUT:**

* The Input for our model will be an image array of 128x128x3 which is the input on which the initial architecture was built, we can use different sizes as well during model tuning.

**Output:**

* Our model will have 2 types of outputs
  + 1. Classification output which predicts the class type (Normal, Lung opacity) so we will add a dense layer for that at the end with 1 neuron.
  + 2. Regression output which predicts the bounding box coordinates for locating the area affected by Pneumonia

**Loss Function:**

* These outputs will be connected to the last layer in parallel.
* For Classification loss function we will use “binary\_crossentrophy” as we have only 2 classes
* For the Regression loss function we will use “mse”(mean squared error).

**Metrics:**

* Classification output uses “accuracy” function
* Regression output will use “IOU”(Intersection over union) custom built function which helps to find out how much the predicted bounding box actually overlaps the affected area accurately.

**Train and Validation sets:**

* As there are more than 30,000 training images we have split this data into 80% of train set and 20 percent of the validation set.

**Image Augmentation:**

* To have variety and expand our data set we will use data augmentation technique which will help to provide different views of the same image.
* If we are augmenting the image, we must also augment the bounding box with it to have alignment.
* For this we will use a package called imageaug by using below commands
  + !pip install imgaug --quiet
  + import imgaug as ia
  + from imgaug import augmenters as iaa
  + Using this package, we have implemented our functions.

**Batch Generators:**

* We will have to train our model by providing the image arrays in batches
* We have fixed the batch size to 32 as of now
* We have written a batch generator function which will provide hold a batch of
  + 32 image arrays of size 128x128x3
  + 32 bounding box coordinates ie 32x(xmin, ymin, xmax, ymax)
  + 32 labels
* Prepare a train\_generator, while creating the batch use the augmentation function.
* Prepare a test\_generator(validation) and no need to augment as this is a validation set

**Checkpoint:**

* Define a callback where we will be monitoring the 'val\_class\_op\_accuracy'.and store the best result and save it as Pneumonia\_detection\_vgg.h5. With (verbose as 1).

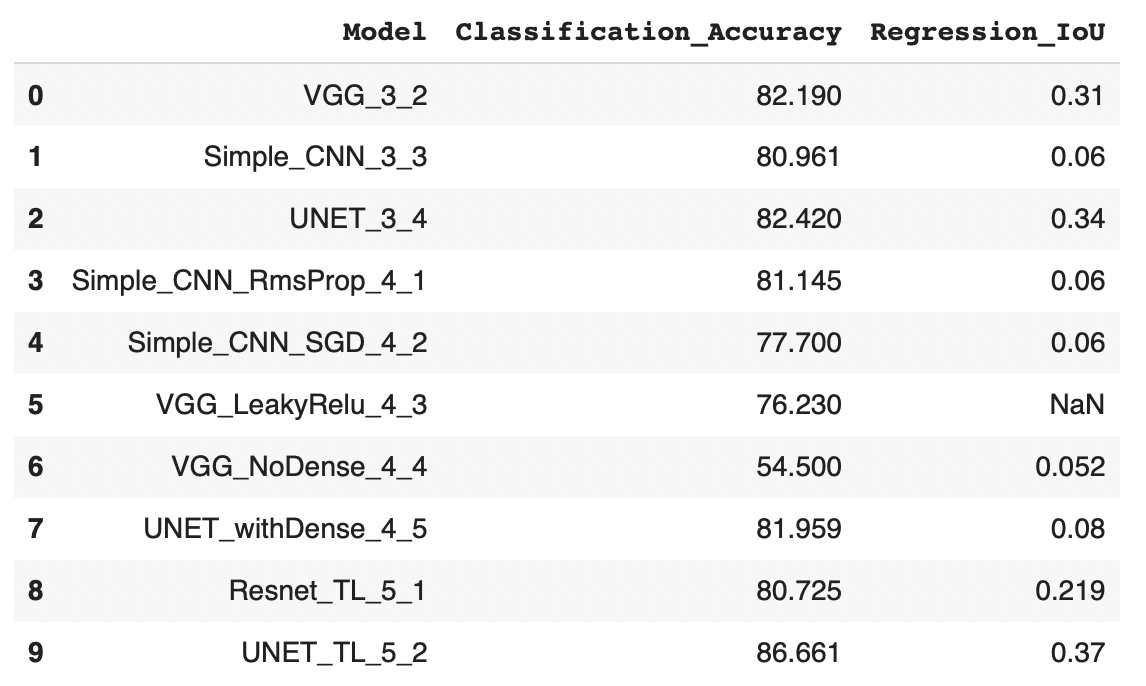
**Model Fit:**

* Model is being fit and trained on 100 epochs and with a batch-size of 64.

**Result:**

* With all these steps we fit the model and ran it for 100 epochs and obtained the below accuracy for classification and regression.
  + Train Iou => 0.33, Validation Iou => 0.32
  + Train\_accuracy => 88.60% , Validation accuracy => 86.66%
* **Model Summary**

**==================**

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**Note :** From our the models we have tried and tested we will finally be moving ahead with **UNet Transfer Learning** **Model** as it has given us the best **(Accuracy Score : 86.66% ) & best (Iou Score : 0.37)**

## Tools & Technology

## The use of right tools and technology is a of utmost importance while reaching our goal during the course of this project.

## Libraries like “Matplotlib” have enhanced our visual representation of the data provided to us. This not only provides us with useful graphical charts, but also provide us with important stats on the data in terms of target classes infecting what percentage of the patients. With the help of this we also get to know what percentage of the data could be lost if we drop key records hence impacting our overall accuracy.

## Other libraries namely “Tensorflow” & “Sklearn” do help us in our model building activities inorder to derive accuracy scores from our filtered data & also in imputing null values to their nearest neighbors hence avoiding the process of dropping excessive data. This could be beneficial in our final accuracy.

## Our entire project is based on computer vision, which we are pursuing by using, google colab as our building platform, csv files our datasets & dicom images for train and test purposes. RAM used thus far for EDA, Preprocessing and Visualization is 2.0GB, GPU being used is nil.

## Coming to the part of model building we are using a VGGNET, ResNet, UNet & Tensforflow object detection api architectures for analysis.

1. **Task in hand**

Tasks we have in hand is, Test the Model, Fine-tuning and Repeat.

• Test the model and report as per evaluation metrics

•  Try different models

•  Set different hyper parameters, by trying different optimizers, loss functions, epochs, learning rate, batch size, checkpointing, early stopping etc. for these models to fine-tune them

•  Report evaluation metrics for these models along with your observation on how changing different hyper parameters leads to change in the final evaluation metric.

1. **Business Impact/Outcome**

With our current analysis and prediction it could help medical advisors to great deal hence limiting human errors, though not entirely at our present accuracy scores. Our study does continue further in exploring, fine tuning and building better algorithms, inoder to streamline the process even further. Hence this could impact the business in the short term, as we strive to excel and make this a more profitable solution for them for the long run.

# Leveraging AI/ML to Drive Growth and Innovation

AI/MLhas been the driving force within most industries in more than a decade. With the growth of computers and its development into even more powerful machines, growth of the internet side by side has proved to be an overall success for not only AI/ML but for the technology industry as a whole. With modern day machinery at our disposal and state of the art algorithms we are able to train large amounts of data and achieve accurate results. This not only helps in fastening the process, reducing labor/hiring cost, but also helps in minimizing human error. With the help of AI/ML researchers are able to analyze, predict information in area which we never thought/heard of before hence opening the doors to an evolution in technology in various fields.

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