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Research Article

Pneumonia Disease Classification by examining Lungs X-ray Pictures using Convolutional Neural Network

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Abstract

Pneumonia is a contagious and fatal illness of the respiratory tract that is caused by bacteria, fungi, or a virus that infects the air sacs of the human lungs. It usually affects the elder people and in worst cases, it can prove to be fatal. The lives of the people can be saved if it is detected early and early treatment is provided. Pneumonia is usually diagnosed using chest x-ray images which are evaluated by a medical expert. To ease this peoblem we will be using CNN a deep learning algorithm approach for Pneumonia Disease diagnosis which gives highly accurate results by examining chest x-rays pictures. So, based on chest x-rays, we will detect whether a person suffers from bacterial pneumonia, viral pneumonia or the person is normal.

Keywords-Pneumonia, Convolution Neural Network, Deep Learning,Adam,Softmax.

1.Introduction

Pneumonia a well known disease that the lungs in the infected person. It is caused by bacteria, fungus, or a virus that infects the air sacs of the lungs and fills them up with discharge fluids. Some of the symptoms of Pneumonia are coughing with bloody mucus, shaking of body due to chills,breathing problems like rapid or shallow breathing, etc. Causes of this disease are many reasons like germs like bacteria and virus. Among these germs, bacteria and virus are the most popular ones. Some other causes are lack of clean drinking water, cleanliness, and basic health facilities. It has killed over a million children in 2018 and remains a deadly disease if not detected and diagnosed earlier. Some of the common methods to detect pneumonia are Radiology, MRI, and CT-scan. The patient’s radiology of chest is examined by medical personnel. Analyzing the x-ray images of the lungs is effective but sometimes they can be ambiguous for pneumonia detection because they can be misinterpreted as lung cancer or other respiratory disease. We have used deep learning model to detect pneumonia and classify it into either of the three categories i.e bacterial, viral or normal. Due to certain limitations of machine learning, we chose deep learning for our project. We have used Convolutional neural networks for detecting pneumonia. In CNN various layers like convolution layer, maxpooling layer, and fully connected layer.

1.1 Problem Definition

In this project, we aim to detect and classify pneumonia using a convolution neural network(CNN).We aim to make a web-based application that will integrate these models.The user will upload his/her chest x-ray image on the web application, the web app will predict whether the person suffers from bacterial pneumonia,viral pneumonia or if the person is normal.

1.2 Motivation

In today's era especially in our country, we can see a shortage of proper diagnostic facilities. Things became more visible and pity in the covid pandemic.As we all know, Covid 19 in serious cases leads to pneumonia of the lungs.And pneumonia is such a disease that if not diagnosed in early stages and if proper treatment is not given,it can prove to be fatal.So to solve this problem we came up with a web application which any person can use by uploading his/her x-ray image and the app can predict whether the person suffers from pneumonia or not. If yes, then what kind of pneumonia –bacterial or viral.As Pneumonia is a fatal disease,so with early detection it can be cured and a person's life can be saved.

2.Literature Survey

A lot of work is already done for detecting and classifying Pneumonia. An author named Deniz Yagmur Urey et al.presented his exploration involving premature observation of Pneumonia using deep learning algorithms. He put Forward a unique and great approach. His research targets the organic or biological look of Pneumonia Disease and identifies them in Chest X-ray pictures. In his research paper he has used Convolution Network furthermore Residual Neural Network. His exploration helps us to identify this Fatal Disease in its pre-mature stage so that rightful treatment can be given to heal it. We got motivated by his work and decided to plan a same evaluation on more large Chest X-ray images through CNN and to produce better results[1].

V. Sirish Kaushik presented a paper for detecting pneumonia from x-ray pictures of the lungs.His carried out with his research with the help of a dataset available on Kaggle.He created 4 different CNN models .The first model had only one convolution layer, second model had 2 convolution layers,the third and fourth model had 3 and 4 convolution layers respectively.All the four models showed good results and achieved high accuracies with th highest accuracy shown by the third model .The accuracy of the third model came out to be 92.31%.[2].

Shanay Shah, in his research paper, has explained how he has used CNN to detect whether the person suffers from Pneumonia or not. The approach he followed had few steps like importing the image dataset, followed by data augmentation. For data augmentation he considered various parameters like flipping an image horizontally, rotating it at a certain angle, zoom range, shear range, etc. Then this pre-processed data was fed to the CNN model. His model achieved very great results. His training accuracy came out to be 96.5%, validation accuracy to be 92.24%, training loss was 0.096, and validation loss was 0.229.He only predicted two classes i.e pneumonia and normal and after going through his paper we thought of predicting three classes by our CNN model i.e bacterial pneumonia, viral pneumonia, or normal. As he predicted only 2 classes, he used sigmoid activation function in the dense layer of the CNN model he created because sigmoid is used for binary classification. We decided to use softmax activation function in our model because we decided on implementing multi-class classification i.e 3 classes for prediction

[3].

3.Approach

Convolutional Neural Network

CNN stands for Convolutional Neural Network.It is used to classify and categorize images from learned features.In image classification, we take an image as an input and it outputs a class(e.g. cat,dog, etc) or a probability that the input belongs to a particular class.

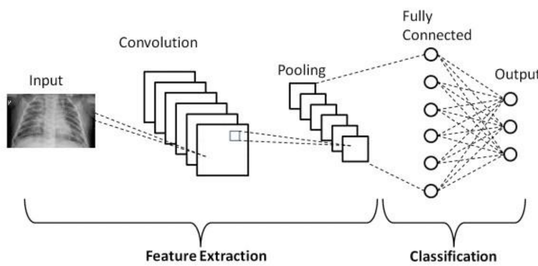


Figure 1 CNN Model Architecture

CNN Layer

This layer conceptualizes the characteristics of every image input. It discovers significant image characteristics and hence helps in storing the three-dimensional connection among pixels with small squares of image input. The kernel, which is a 3X3 matrix is used to find the dot product by sliding over the input image, and then the dot product is summed together in a single value. This helps to compute the feature maps for the next layer.

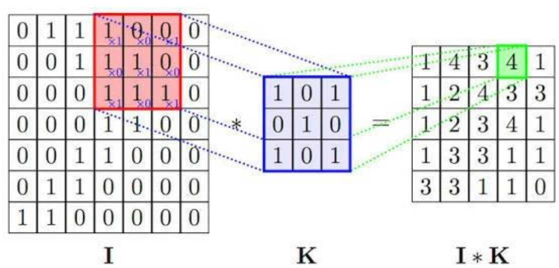


Figure 2 Demonstration of Convolution Layer

Max pooling layer

This layer performs pooling operation.Forthat,the kernel convolves and selects the largest value from feature map. This figure shows how 4x4 matrix pixel values of an input image are degraded into 2x2 filters.

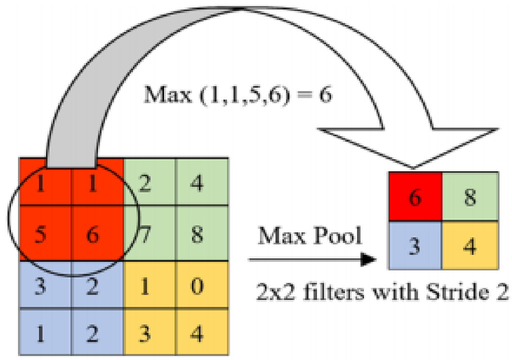


Figure 3 Illustration of Max Pooling Layer

Fully connected Layer

Multi-layer perceptron during this layer confirms that each one neuron is interconnected to each neuron of each succeeding layer in the purpose of classifying input images created through the preserved features of the image.

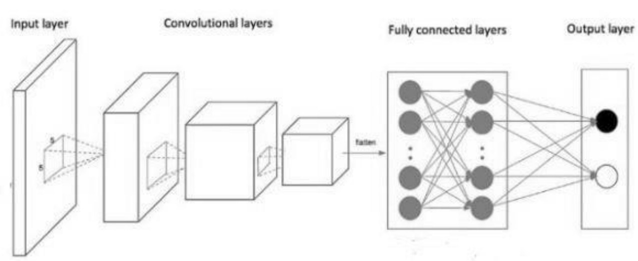


Figure 4 Interconnected layer

4.System Design

This is our proposed System Design. Here we first imported our Chest X-ray Image Dataset. Then we performed Exploratory Data Analysis where we processed our image. We converted our images into RGB which were then resized and after that, we converted them into NumPy array. Then we divided it by .1/255 for scaling as we were working withimage dataset. Then after that,we performed Data Augmentation because we knew that we have a small dataset and there were alot of variations such as height/width ratio,zooming range, e.t.c in them. Then after Data Augmentation, we built a CNN model sequential based. Then we compiled our model with optimizer adam. Then we went for model training using model.fit_generator. After that, wevisualized the accuracy of our model through a graph. Then we saved our model and deployed it.

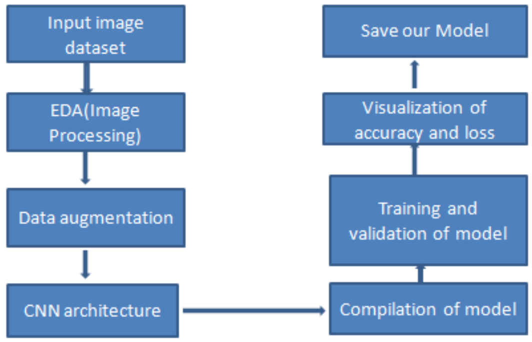


Figure 5 System design

5.Implementation

5.1 Dataset Description

We have used Mendeley Public datasets repository for our dataset Chest X-ray images. Our Chest X-ray pictures data is branched into different folders for training,testing and validation.Each of these folders contains subfolders of image class. In our dataset there are total 5,863 pictures and 2 classes Pneumonia(Bacteria and Virus) and Normal(Not infected). All xray pictures(front and back) selected are of children whose age lie between 1 - 5 years taken from a medical center in Guangzhou(Hong Kong) [4].

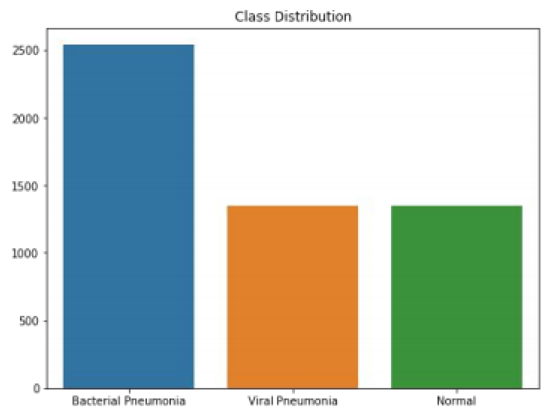


Figure 6 Class Distribution

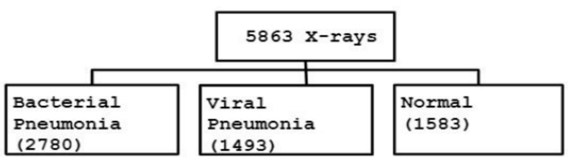


Figure 7 Dataset Categories

5.2 Dataset Preprocessing and Exploratory Data Analysis

Most images were at least 224 × 224 pixels and contained RGB color channels. Images that were smaller than 224 x 224 pixels or in greyscale were removed from the analysis. This was done after getting poor results with preprocessed images to smaller size and grayscale mode even though it gives faster results.

A function called pair plot was defined to plot the normal and pneumonia positive images side by side to get a glimpse of the difference. Pneumonia positive images seem to be fainter as the borders between organs are less sharp because of the soft tissue (water) in the lungs.

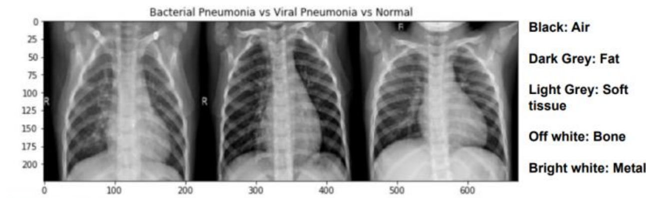


Figure 8 Comparison Plot

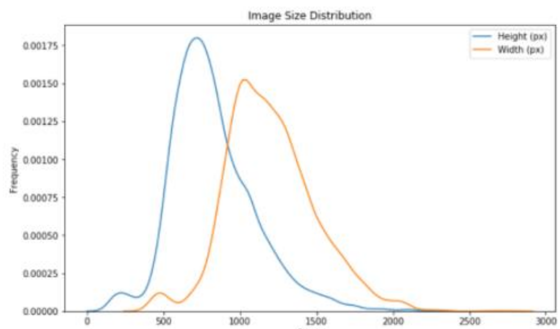


Figure 9 Image size distribution(px)

5.3 Data Augmentation

The X-ray images were resized as (224 x 224 x 3) three-dimensional tensors so that they all have the same number of input variables. Also, the pixel values were downscaled multiplying by .1/255 to avoid extremely high output values.

All images were manually reviewed and found that there are a lot of variations for such a small dataset. The height/width ratio, zooming range, angle of the body, etc features differ among different X-ray images. Even the physical dimensions of images are vastly different. This makes it harder to train a model that will give a high accuracy rate. Image data generator class was utilized to generate additional images within train data with optimal rotation_range, shear_range, zoom_range, horizontal_flip (mirroring randomly selected images) to get additionalobservations to train the model with. The augmentation occurs on the fly during the training process and a slightly different version of each image is used as input per epoch. The parameter values were tuned numerous times until getting decent predictive performance from models.

After the data generator object was initialized with optimal parameter values, the directory iterator method flow_from_directory was used to generate batches of NumPy arrays of augmented images from the train directory. For validation images, only rescale parameter was used since augmentation is necessary to improve the learning process but not for validating.

A function called plotImages was defined to plot random variations of same X-ray image. The function was executed numerous times to make sure the most informative areas (lungs) would not be cropped from the images with given parameter values.

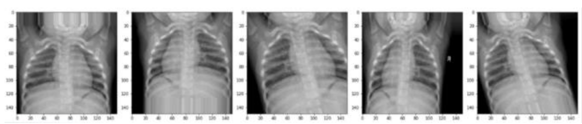


Figure 10 Data augmentation: Final versions of the same image

5.4 Neural Network Architecture

The data was fit to a series of simple sequential and convolutional networks. With the guidance of success metrics on both train and validation data, the complexity of the models were gradually increased and the parameters were tuned for the best performance.

CNN Architecture

We have first made a sequential Convolutional Neural Network Model then we have initialized it and added the following layers:

- Firstly a convolution layer of 32 filters with 2 X 2 Kernel and activation function Relu is added.
- Then after that 1 X maxpool layer of 2 X 2 pool size layer is added.
- After that we have added a convolution layer of 64 filters with 3 X 3 Kernel and activation function Relu.
- 1 X maxpool layer of 2 X 2 pool size layer is added.
- After that we have added a convolution layer of 128 filters with 3 X 3 Kernel and activation function Relu.
- Then after that 1 Xmaxpool layer of 2 X 2 pool size layer is added.
- After that we have added a convolution layer of 256 filters with 3 X 3 Kernel and activation function Relu.
- Then after that 1 x maxpool layer of 2 X 2 pool size layer is added.
- After that we have added a convolution layer of 512 filters with 3 X 3 Kernel and activation function Relu.
- Then after that 1 Xmaxpool layer of 2 X 2 pool size layer is added.
- Then we have added a Dropout of 0.5 units to avoid overfitting.

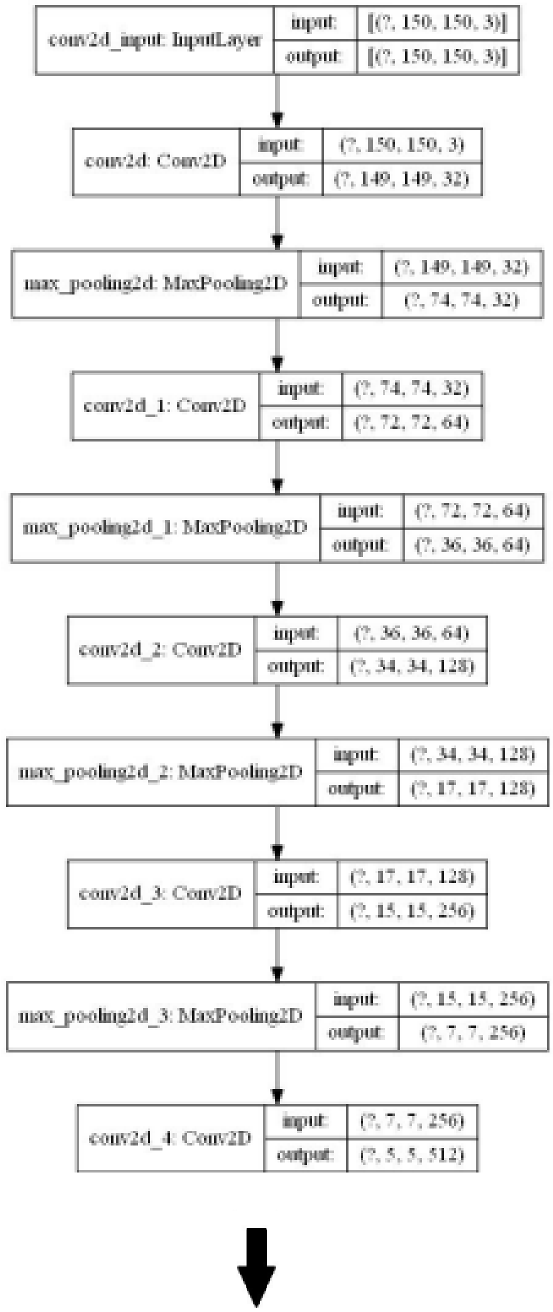
These are all convolutions then we have passed the layer to the Dense layer. Then we have added following layers there.

- We have also used 1 Flatten layer to flatten the vectors which are coming out from the convolutions.
- After that we have added a Dense layer of 1024 filters with activation function Relu.
- Then we have added a Dropout of 0.1 units to avoid overfitting.
- After that we have added a Dense layer of 1024 filters with activation function Relu.
- Then we have added a Dropout of 0.05 units to avoid overfitting.
- We have also added 1 X Batch Normalization layer.
- Then at the Last Layer we have added a 1 X Dense Layer of activation function softmax of 3 units.

As we have added DenseSoftmax activation layer in the end as we have to predict 3 classes Normal, Bacterial Pneumonia, and Viral Pneumonia. Then we go for Model compilation by taking the activation function as adam. Then we go for Model Training using model.fit_grenerator().

After a series of trials, it's discovered that the network learns from the data gradually so the initial layers have fewer neurons than the middle layers. Also, multiple Dropout layers were added with optimal rate to combat overfitting. Decreasing the learning rate to "slow cook" the network did not affect the accuracy much so it was kept with a default value. Instead, epochswere increased to 250 so that the data size would be artificially boosted each iteration. We added BatchNormalization layer before the outputlayer.As the network becomes deeper, batch normalization starts to play an important role.

Since 250 epochs take a very long time to execute, the weights would then we saved our model in .hdf5 format.


conv2d_input: InputLayer
input: [(?, 150, 150, 3)]
output: [(?, 150, 150, 3)]
conv2d: Conv2D
input: (?, 150, 150, 3)
output: (?, 149, 149, 32)
max_pooling2d: MaxPooling2D
input: (?, 149, 149, 32)
output: (?, 74, 74, 32)
conv2d_1: Conv2D
input: (?, 74, 74, 32)
output: (?, 72, 72, 64)
max_pooling2d_1: MaxPooling2D
input: (?, 72, 72, 64)
output: (?, 36, 36, 64)
conv2d_2: Conv2D
input: (?, 36, 36, 64)
output: (?, 34, 34, 128)
max_pooling2d_2: MaxPooling2D
input: (?, 34, 34, 128)
output: (?, 17, 17, 128)
conv2d_3: Conv2D
input: (?, 17, 17, 128)
output: (?, 15, 15, 256)
max_pooling2d_3: MaxPooling2D
input: (?, 15, 15, 256)
output: (?, 7, 7, 256)
conv2d_4: Conv2D
input: (?, 7, 7, 256)
output: (?, 5, 5, 512)

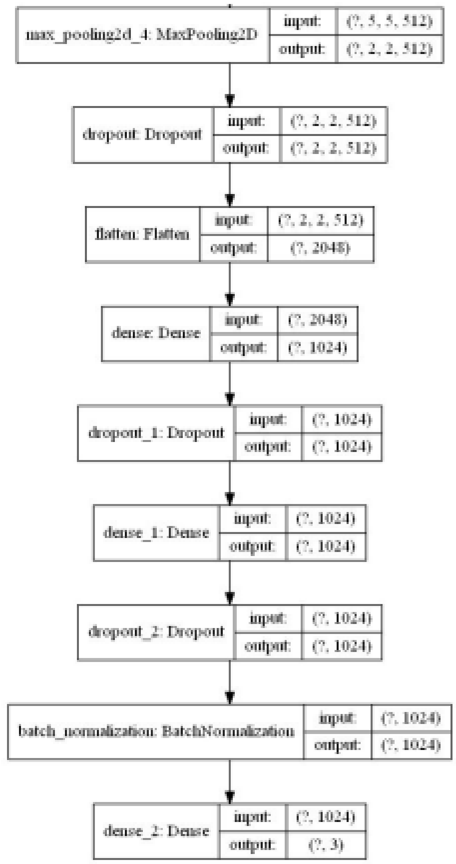


Figure 11 Final CNN architecture

6.Result Analysis

The training/validation accuracy and loss graphs were created from 100 epochs version of the above convolutional network. It may be considered a time-series graph of the network's performance. The model learns gradually but the overall performance has an upward trend. The X-ray images from different classes are very similar that, the network captures the most informative inputs after numerous iterations and weight adjustments.The training accuracy came out to be 89.34%,validation accuracy 87.34%,training loss27.02%, and validation loss 40.26%.The model learnedbacterial pneumonia the best as it is the majority class with the highest number of observations. However, true positive and true negative rates for both normal and viral pneumonia are not too high either. Only five patients were classified healthy while they have bacterial pneumonia. Asbacterial pneumonia is the most fatal, it is recommended to minimize this value which would optimize the recall score. Perhaps by increasing the complexity of the model.

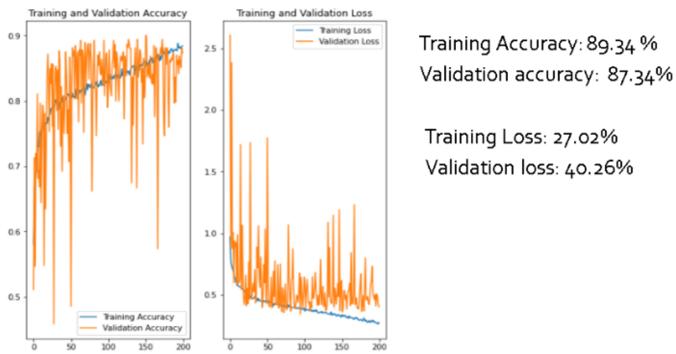


Figure 12 Accuracy and Loss plot

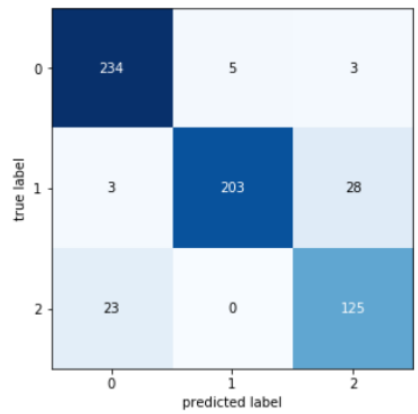


Figure 13 Confusion matrix for the final model

In the above confusion matrix,0 corresponds to bacteria, 1 corresponds to normal and 2 corresponds to virus.

7.Deployment

We built a web application in which user uploads his/her chest x-ray image and the application gives the probability rates for 3 different classes:

1- Normal/Not infected by Pneumonia

2- Pneumonia (Bacterial)

3- Pneumonia (Viral)

For the app, saved weights of the best model was loaded to the empth CNN arthitecture. Then, the user input was passed to the data iterator method of Keras data generator object, finally evaluated by the model to generate predicted probabilities of each of the three classes.

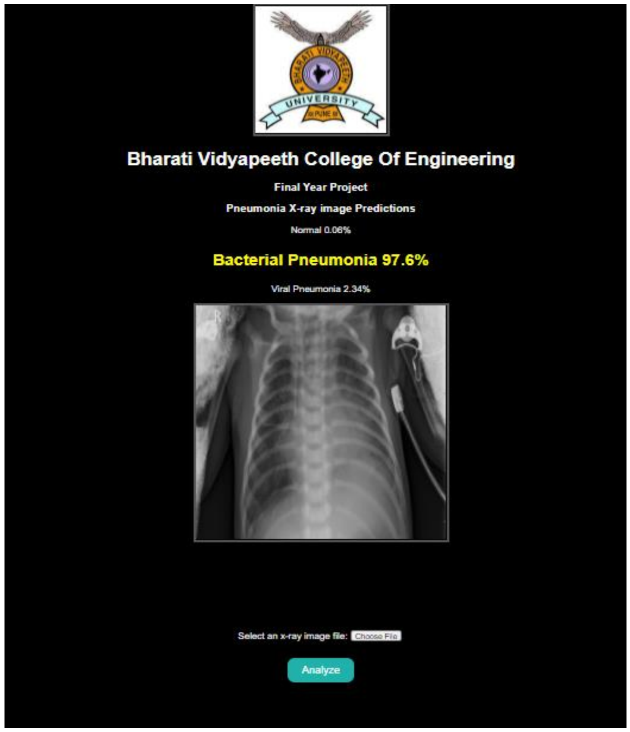


Figure 14 Image classified as bacterial pneumonia

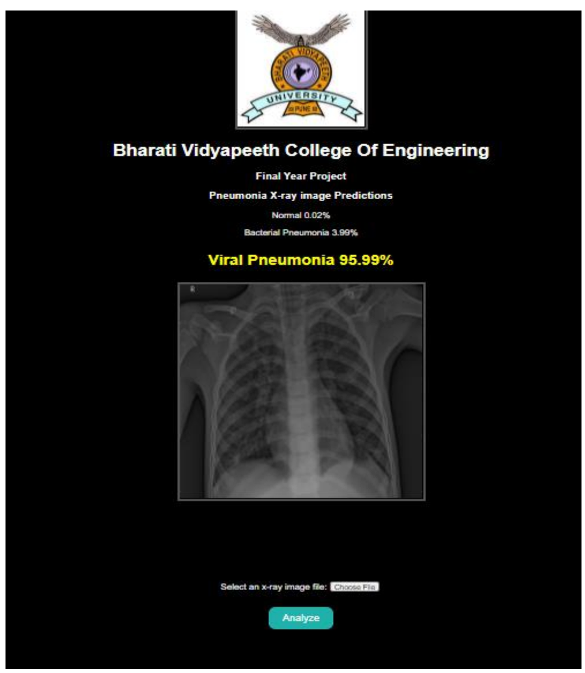


Figure 15 Image classified as viral pneumonia

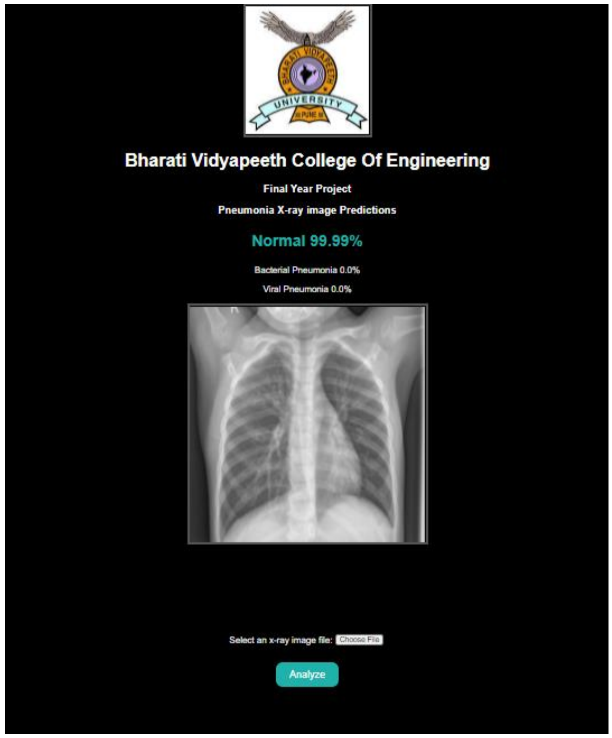


Figure 16 Image classified as normal

6.Conclusion

So after completing our Project we came to conclude that the Convolution Neural Network which we have created, works in a well efficient manner and is able to examine properly. As we keep on increasing the epochs,the accuracy of our model keeps on going up gradually and the loss comes down. We can increase the performance of our model by performing dataset preprocessing and data augmentation as the initial steps.We have used a dropout layer to avoid the condition of model overfitting. Our model is able to Classify Chest X-ray image properly whether the image is Normal , Pneumonia(Bacterial) , Pneumonia(Viral). This project will be very helpful in the premature and precise identification of Pneumonia.As pneumonia is a deadly disease,early diagnosis is very important to save a person's life.Hence,our project is of tremendous use in medical and healthcare fields.

7.Future Scope

As we all know that the deadly corona virus , which is the ongoing pandemic, also infects the lungs and in severe cases it leads to pneumonia. So, in future we can extend our model to even detect corona virus using the chest x-ray images and various deep learning techniques. It will help save the lives of many people and also, it will reduce the danger of spreading the virus to the doctors and the staff. Our model can also be extended to detect various stages of Pneumonia so that if the disease is detected early, proper treatment can be given to the patient and his/her life can be saved. We can use this model to detect various other lung related disorders like cancer of the lung or asthma. The deep learning method which we have used is fast and also gives accurate results. Thus, the scope of this project is tremendous especially in medical and healthcare fields.

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