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# Deep Learning on Chest X-Ray Images for Lung Abnormality Detection to Identify COVID-19 And Pneumonia

**Shawn Chauhan[1]**
University of Southern California (Class of 2024)
Bachelor of Science: Computer Science & Business Administration

**Reetu Jain[2]**
Chief-Mentor of On My Own Technology Private Limited Mumbai

*Abstract:* The novel coronavirus (COVID-19) has infected over 131 million people worldwide and killed nearly 3 million. It is extremely disheartening to witness the world suffering from this pandemic which has taken the lives of so many.. At the moment, according to WHO COVID-19 is considered one of the most dangerous diseases caused by this novel coronavirus which was found to have originated in Wuhan (China) towards the end of 2019. An early diagnosis of COVID-19 through effective means, such as X-ray images, can greatly help in reducing the fatality rate of this disease by preventing it from developing into Pneumonia. In this research, we suggest an efficient means to detect COVID-19 and Pneumonia with the help of a deep learning algorithm which can give results up to an 87% accuracy. One of the most important aspects of this research paper is that we've built our own deep learning algorithm to distinguish between Pneumonia, COVID-19, and normal lungs using an X-ray image dataset to teach the algorithm.

*Keywords:* COVID -19, Pneumonia, X-ray Diagnosis, Lung Abnormality detection, Machine Learning, Deep Learning.

**Introduction:**

As we transitioned into 2020, we as a society were faced with an unprecedented challenge (COVID-19) that we are still struggling to tackle today. Although the virus first originated in Wuhan, China, it has now spread to over 220 countries with about 152 million cases and 3.2 million deaths. The increasing number of cases has put immense pressure on our health systems that cannot cope with producing vaccines, ventilators, or oxygen for severe patients. Taking into account the time that it takes to correctly diagnose COVID-19 and the additional charges for producing detection kits, implementing Artificial Intelligence (AI) and Deep Learning algorithms is greatly helping doctors in diagnosing COVID-19 among patients effectively. This research essentially makes use of a Deep learning algorithm to successfully detect COVID-19 in patients using X-ray images. This will not only help in faster detection but also create less of a financial burden on our healthcare system.

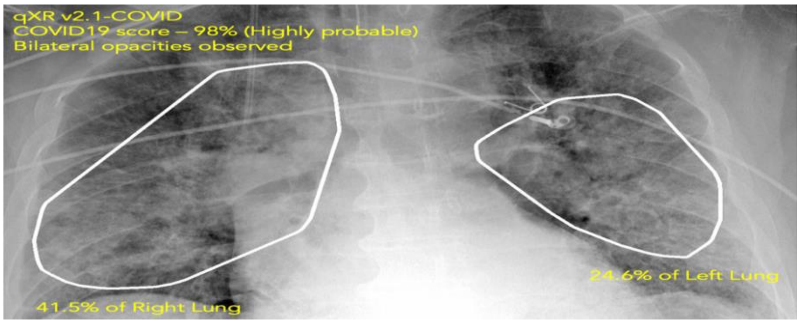



Figure [A]: Displays the Detection of COVID 19 using an X-ray image by a Doctor

Today, due to the drastic rise in cases, rapid COVID-19 tests which usually take between 3 to 48 hours to give results, are now taking a few days at times due to the immense pressure faced by our healthcare systems. As a result of this, a statement released by the Fleischner Society suggested the use of chest radiography images for patients suffering from COVID-19 when experiencing limited resources and no access to Computed Tomography (CT). The reduced financial pressure as a consequence of using X-ray images for COVID-19 detection will allow hospitals in drastically impacted countries such as India to automatically determine whether the patient has the disease at almost no additional costs of testing kits. Moreover, this will allow for an almost immediate detection system allowing doctors to advise patients on their situation at a faster pace.

Deep Learning within AI has gained a very positive reputation for handling image classification-based tasks during the past few years. This research too makes effective use of Convolutional Neural Networks (CNN) in order to diagnose X-ray images for COVID-19. It analyzes parts of the image through multiple layers and then concludes whether the patient has COVID-19 with an 87% accuracy. The developed CNN model is able to efficiently detect COVID-19 with a very high accuracy and this will be very useful in creating a more streamlined system where doctors can detect this disease at a faster pace.

**Related studies**

Pneumonia Detection using machine learning has been a field that is widely researched. And the most prominent hurdle is the non-availability of properly labeled data sets. Rohit Kundu et al. [7] proposed a transfer learning based deep learning method which helps them to deal with the less amount of data available. They designed an ensemble of three CNN models based on GoogLeNet, ResNet-18, and DenseNet-121. Their method achieved an accuracy of 86.5% on the RSNA dataset. They also combined four evaluation metrics and formed a single weighted vector to evaluate their model. ShangJie Yao et al. [8] presented a paper where they proposed a 2-stage detector based on faster R-CNN. They used a DeepConv-DilatedNet for identifying and localizing pneumonia. Kuang Ming Kuo et al. [9] did a study on 185 schizophrenic in-patients. They recorded 11 parameters and used various machine learning algorithms to predict the onset of pneumonia. They concluded that random forest and decision trees were the best algorithms to predict the pneumonia onset. Sharma et al. [10] used a CNN based method to classify chest X-ray images. They have used data augmentation methods to account for the non-availability of data. This allowed them to attain high accuracy even when the model was trained on less data. The data augmentation techniques used were rotation and scaling.

With the onset of COVID-19 and the load that it has put up on the medical system has led to a lot of research in this field in a very short amount of time.
Aditya Saxena et al. [11] in their research paper has proposed a Deep convolutional neural network based machine learning algorithm. The model gives a binary output. They have claimed to have achieved a higher accuracy when compared to 4 other Convolutional neural network-based algorithms. Rubina Sarki et al. [12] compared various state of the art models and then evaluated them against their own custom CNN model. Binary classification of the chest X-ray into covid/normal gave them an 100% accuracy when they tried it out on their model. They also trained a model which marks the regions in a X-ray where the chances of finding COVID. This model had an accuracy of 83%. Mundher Mohammed Taresh et al. [12] has proposed to use a pretrained CNN to classify and detect whether the chest X-ray has COVID-19 or Pneumonia. They used a data set which contained 1200 CXR images with COVID-19, 1345 CXR images with viral pneumonia and 1341 images of normal individuals. They used a VGG16 and MobileNet model to predict the results. The authors have claimed a prediction accuracy of 98%.

**Project Working Principle**

The comprehensive intention of the present study is to develop a deep learning model to detect and predict the COVID-19 and Pneumonia from the X-ray images. Convolution neural network (CNN) is an unsupervised deep learning algorithm that is capable of extracting useful information called features from images and using those in predicting and classifying the output labels. The pictorial diagram of the working principle is shown in figure [B].

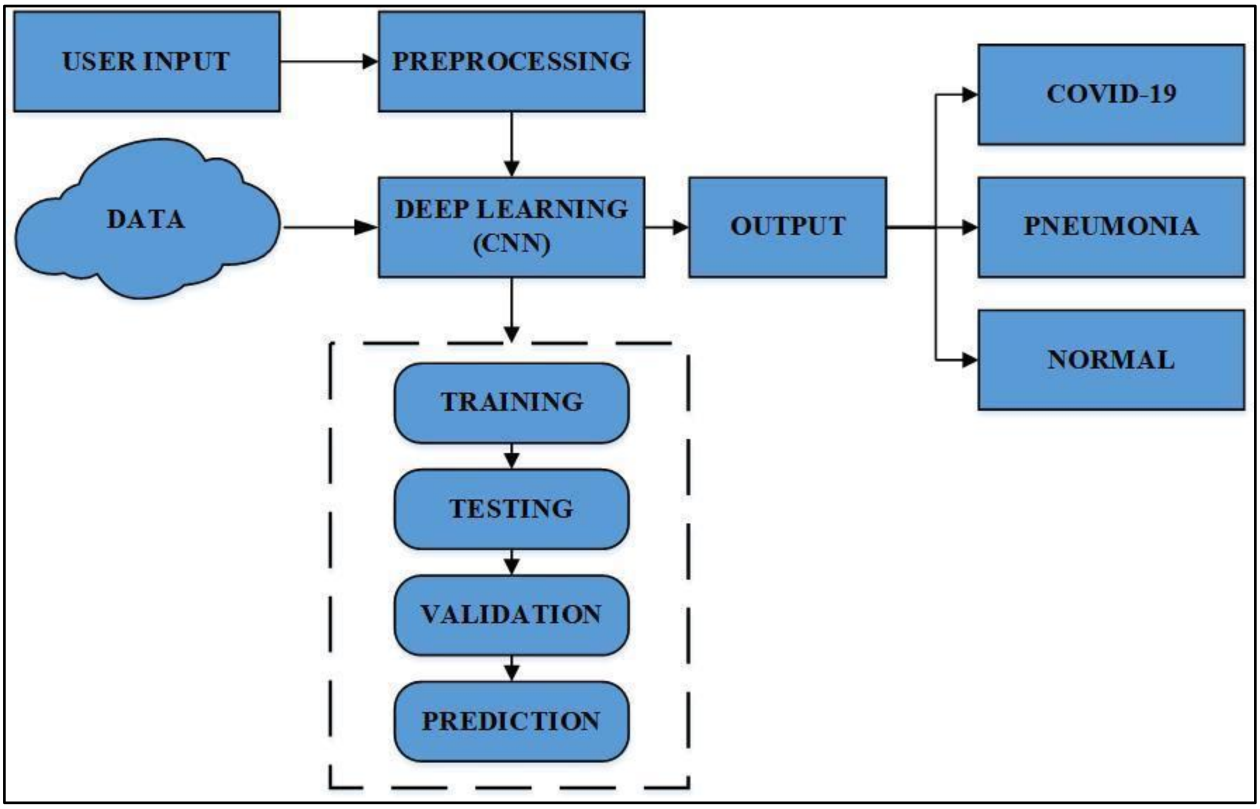


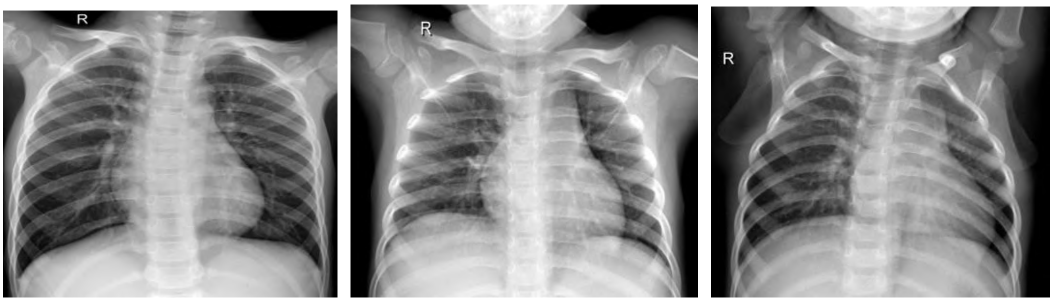

Figure [B]: Working Principle of Detecting COVID-19 using X-ray images

**Data acquisition**

The CNN model is a data-driven machine learning technique that is trained using images. The images for the present study are X-ray images of the chest cavity. In the study, the dataset is downloaded from Kaggle which has Chest X-ray images for COVID-19 and Pneumonia. The dataset comprises 1800 images, out of which 300 images are used for testing and validation and the remaining 1500 images are used for training the CNN model. This automated model allows for the immediate detection of the disease, saving a lot of time for the patient as well as the doctor. Few sample images from the data representing various classes are shown in the figure [C]

*X-Rays marked as COVID-19*

*X-Rays marked as Pneumonia*



*X-Rays marked as Normal*

Figure [C]: Sample images from the data representing various classes

**Machine learning model:**

The machine learning (ML) technique applied in the present study to identify COVID-19 and Pneumonia from X-ray is the Convolution Neural Network (CNN). It mimics the biological process of connectivity organization of the animal visual cortex and due to this reason CNN is the most widely used ML model to extract features from images and then map them to label **[1]**. Over the last decade, CNN has been used in complex problems ranging from disease detection, agricultural applications, pattern recognition, from image processing to voice recognition. The most beneficial aspect of CNNs is reducing the number of parameters in ANN. This achievement has prompted both researchers and developers to approach larger models in order to solve complex tasks, which was not possible with classic ANNs. The most important assumption about problems that are solved by CNN, is that it should not have features which are spatially dependent.

Similar to other ML techniques, CNN is divided into two parts. The first part is training, and the second part is testing. In the training part, the model is determined for all good values of weights and the bias from labeled examples. On the other hand, in the testing part the model is tested for a sample dataset. The predicted label is then compared with the actual label to determine the accuracy and preciseness of the model created **[2]**. The steps for CNN involve:

i. Convolution operation.
ii. Activation operation.
iii. Pooling operation.
iv. Layer stacking.
v. Fully connected operation.
vi. Classification and prediction

**Convolution operation**

The convolution operation of CNN is used to extract the features from the training images and excludes the irrelevant noises. The convolution operation divides an image into tiny and smaller fragments so that the features of the images could be easily extracted, and the irrelevant noises could be dropped down. This fragmented image is termed an image matrix. The layer containing the N filter matrix is slid over the image matrix throughout its width and height. Matrix multiplication of the image and filter matrix give the resultant matrix termed as convolution matrix. The pictorial diagram of the feature and filter matrix to form the convolution matrix is shown in figure **[**D**]**.

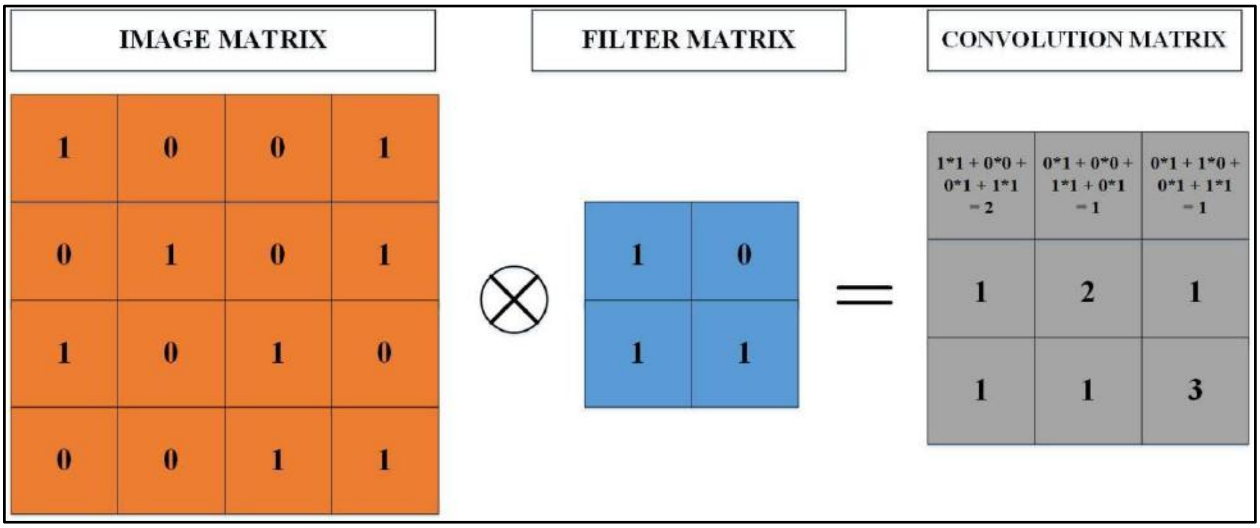



Figure **[**D**]**: Pictorial representation of the convolution operation

**Activation operation**

In neural networks, the activation operation of a node defines the output of that node for a given input or set of inputs. In this paper, rectified linear unit (ReLU) is used as the activation operator. The ReLU is mathematically expressed as:

$$y = \varphi(x) = \{0, if\ x \leq 0\ x, if\ x\ > 0 \qquad (1)$$

ReLU, compared to sigmoid function or similar activation functions, allow faster and effective training of deep neural architectures on large and complex datasets **[3]**.

**Pooling operation**

The pooling operation reduces the number of learning parameters and thereby the amount of computational work to be performed is reduced. This operation is useful to summarize the feature present in a region of the feature map generated by the convolution layer. Pooling operation in CNN is done mostly by average pooling and maximum pooling. In Average Pooling operation, the average value for patches of a feature map, and uses it to create a down sample. However, the major disadvantage of using average pooling is that if there are more than one outlier it does not give the accurate result. This can be overcome with the use of maximum pooling where the maximum value for patches of a feature map is used **[4]**.

**Layer stacking**

In layer stacking operation, the convolution operation, activation and pooling operation is repeated until the output obtained is a minimized matrix of the input image.

**Fully connected layer**

This is the last layer of a CNN model. This layer comprises neurons that are fully connected to the neurons from the previous layers. This is why this layer is called a fully connected (FC) layer. This layer is responsible for classifying and predicting the output or label of the input class.

**Classification and Prediction**

Classification is categorization and each neuron of the FC layer is mapped with a label. The FC layer predicts the label of the input class that has a maximum number of features similar to the testing images. In this study, SOFTMAX activation function is used to classify the label. The SOFTMAX activation function is used for predicting a multinomial probability distribution **[5]**. The mathematical expression for SOFTMAX activation function is:

$$\sigma(z)_i = \frac{e^{(z)_i}}{\sum_{j=1}^{K} \quad (e^{z_j})} \qquad (2)$$

The list of classification is shown in table [1].

**Table 1:** List of classification

| Sl. No. | Classification | |
|---|---|---|
| | **Normal/Abnormal X-ray** | **COVID-19 / Pneumonia** |
| **1** | Normal | --- |
| **2** | Abnormal | COVID-19 |
| **3** | Abnormal | Pneumonia |

The diagrammatic representation of the CNN model developed for the study is shown in figure [E]

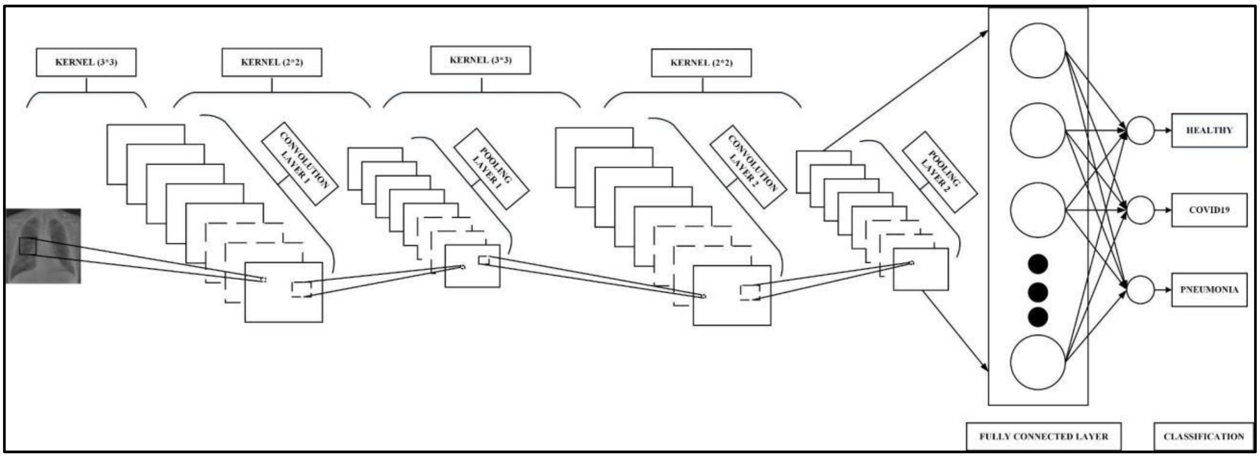
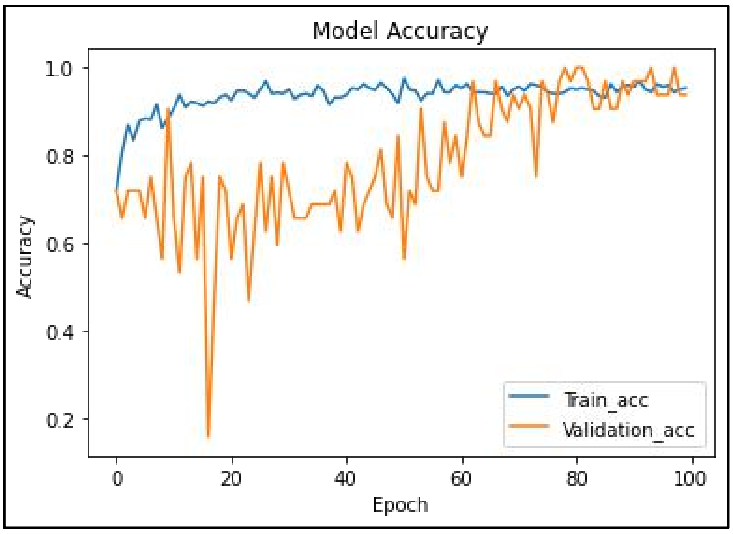


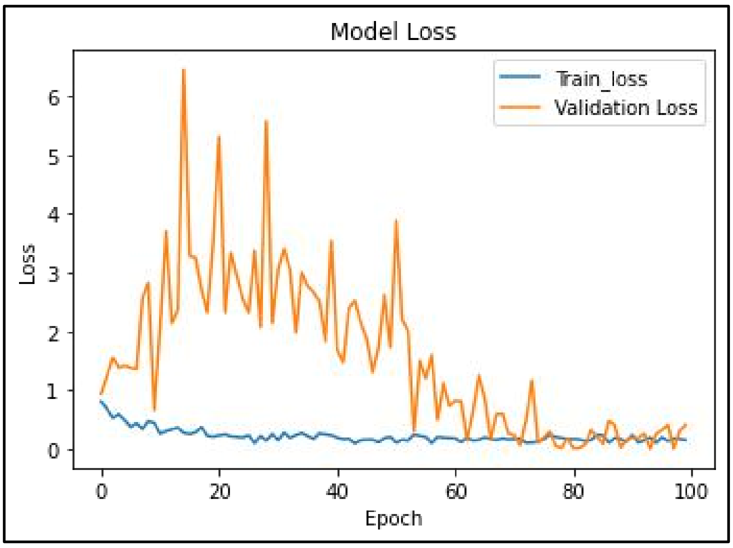

Figure [E]: Diagrammatic representation of the CNN model

**Test Results**

The CNN model is built using the Keras framework which is coded in python 3.8 and runs on a 64-bit windows 10 system with 8 GB RAM and i5, 1.6GHz processor. The CNN model is optimized using Adam optimizer. The Adam optimizer inherits the positive attributes of the “Gradient Descent with Momentum” and “Root Mean Square Propagation” algorithms. The proposed CNN model is executed for 100 epochs with 9 steps per epoch and 1 validation step. The epoch that showed the least loss value is selected as the optimal model. The accuracy and loss graph obtained from the CNN model after applying it to the case study is shown in figure [F].




(i)




(ii)

Figure [F]: (i) Accuracy and (ii) loss curve of the CNN model

The training loss and accuracy computed by the 1$^{st}$ epoch of the CNN model is 0.8034 and 0.7188 respectively. The loss and accuracy values were further enhanced to 0.1908 and 0.9375 respectively. The validation loss and accuracy computed for the 1$^{st}$ epoch is 0.9352 and 0.7188 which was enhanced to 0.225 and 0.9503 respectively for the optimal epoch.

**Conclusion**

The comprehensive intention of the present study is to develop a CNN model to classify COVID-19 from Pneumonia from the chest X-ray images. There exists a lot of literature that applies CNN for disease detection. However, hardly any paper that involved the application of CNN to classify COVID-19 from Pneumonia using chest X-ray images. In this paper, to achieve this objective a CNN model is built using the Keras module which was coded in Python 3.8. The CNN model is trained using 1500 chest X-ray images and 300 images were used for testing the CNN model. The training and testing accuracy for the optimal CNN model is 0.9375 and 0.9503 respectively. On the other hand the loss value for the training and testing is 0.1908 and 0.225 respectively. One of the limitations this model faces is the fact that it has a small sample size of images which restricts its accuracy. However, this can be improved by collecting newer images and training the algorithm with those images. In essence, this model makes use of reliable data and can definitely be improved as we move further. From the overall discussion, it can be concluded that the CNN model proposed in the paper can be applied for detecting and identifying the COVID-19 and Pneumonia from chest X-ray images.

**Acknowledgment**

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**Data repository**

The data considered for the present study is stored in the Kaggle repository at the following link:
https://www.kaggle.com/mohanmkshirsagar/prediction-for-COVID19-normal-pneumonia-using-seq/edit/run/57234536

The code for the study is stored in the following link:
https://www.kaggle.com/code/iltafhussain/covid-19-cnn

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**Authors**

***First Author:***

**Shawn Chauhan**

University of Southern California (Class of 2024)
Bachelor of Science: Computer Science and Business Administration,

***Second Author:***

**Reetu jain**

Chief-Mentor and Founder Of On My Own Technology Private Limited Mumbai, reetu.jain@onmyowntechnology.com