Determination of onset of mucormycosis using image analysis followed by AI-ML data analytics

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CERTIFICATE

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*It is certified that the project work entitled "**Determination of onset of mucormycosis using image analysis followed by AI-ML data analytics**" is being submitted by **Mr. Yogeshwar Prasad Lohiya (Roll no. 180107074)**, for partial fulfillment of the requirement for the award of BACHELORS OF TECHNOLOGY, is a record of bonafide work carried out under my supervision in the Department of Chemical Engineering, IIT Guwahati and this work has not been submitted to any other institute or university for award of any degree.*

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ABSTRACT

Pulmonary mucormycosis (PM) is a very uncommon pulmonary fungal infection that is difficult to diagnose and treat early. Patients with hematological malignancies, diabetes, and immunocompromised states are the most likely to develop it. The fungus feeds on decomposing food, dirt, and animal waste. Pulmonary mucormycosis is challenging to diagnose clinically, and early detection is critical for this life-threatening infection. For early detection, Image analysis with the help of artificial intelligence can be a potential approach. Processing enormous amounts of data by hand is a difficult task. Artificial intelligence and machine learning algorithms come in handy in this situation. The use of machine learning and artificial intelligence (AI) speeds up data processing and produces high-quality image results.

This study reviews different types of mucormycosis and will primarily focus on "Pulmonary mucormycosis". We will also compare the chest x-ray findings of Pulmonary mucormycosis with COVID-19 and other types of pneumonia. This study aims to develop an algorithm that can classify Pulmonary mucormycosis, COVID-19, and different kinds of pneumonia using image analysis. To achieve this, two freely available datasets are taken. The 1st dataset contains images of Normal and Pneumonia chest x-rays. The 2nd dataset includes images of Pneumonia, COVID-19, and Mucormycosis chest x-rays. Two Convolution Neural Networks (CNN), with the help of transfer learning, are used to classify the data. The training and testing set accuracy of the first model were 93.15% and 95.80%, respectively, and the same for the second model were 88.85% and 92.07%.

Keywords: Pulmonary mucormycosis, COVID-19, Pneumonia, Chest x-ray, Image analysis, Convolution neural network, Transfer learning.

INTRODUCTION

Mucormycosis is a term for fungal infections caused by a group of fungi known as mucormycetes. Any organ, including the skin, nasal cavity, orbits, brain, lungs, and gastrointestinal tract, can get infected. There are five most common types of mucormycosis: Rhinocerebral, Pulmonary, Cutaneous, Gastrointestinal, Disseminated. Rhinocerebral mucormycosis is an infection in the sinuses that can spread to the brain. Pulmonary mucormycosis is an uncommon disease that affects individuals who have had chronic neutropenia, such as those who have had a solid organ or hematopoietic stem cell transplant. Patients who have been recommended the iron-chelator deferoxamine are likewise in danger. Young children are more likely than adults to develop gastrointestinal mucormycosis. Antibiotics, surgeries, or medications that impair the body's ability to fight germs and sickness put premature and low-birth-weight infants under one month of age in danger. Cutaneous mucormycosis happens when fungi get into the body through a skin breach. After a burn, scrape, cut, surgery or other skin trauma, this type of infection can develop. When an illness spreads through the bloodstream to another portion of the body, it is disseminated mucormycosis.

Mucormycosis has been recorded in COVID-19-infected patients; however, it is less common than other COVID-19-related fungal diseases. According to recent findings from India, healthcare providers should examine this infection in patients with severe COVID-19, even if they lack traditional risk indicators for the condition. Although imaging findings can be nonspecific, a few radiologic signals can help with diagnosis. Artificial intelligence can simplify this process. We have used two datasets to develop an algorithm that can classify a chest x-ray as one of the following: Normal, Pneumonia, COVID-19, Mucormycosis. The algorithm is based on Convolution neural networks (CNN) because of their incredible ability to work with the image data.

LITERATURE REVIEW

2.1 Mucormycosis and its types:

As discussed earlier, there are five most common types of mucormycosis: Rhinocerebral, Pulmonary, Cutaneous, Gastrointestinal, Disseminated. Here we will discuss them in detail.

- *Rhinocerebral mucormycosis:* It is the most common kind in diabetics and those who have had a kidney transplant. It also affects neutropenic cancer patients, as well as those who have received a hematopoietic stem cell transplant or a solid organ transplant. Unilateral face swelling, nasal or sinus congestion or pain, headaches, fever, and serosanguinous nasal discharge are all possible symptoms. Loss of extraocular muscle function, proptosis, ptosis, and visual impairment may occur as the infection spreads.

- *Pulmonary mucormycosis:* Patients with hematologic malignancy or severe neutropenia are more likely to develop it. Cough, fever, dyspnea, and chest pain are some of the nonspecific symptoms. Tissue necrosis occurs as a result of angioinvasion, which can lead to cavitation and/or hemoptysis.

- *Cutaneous mucormycosis:* It may be primary or secondary infection. Primary infection is caused by the fungus directly inoculating itself into disturbed skin. It is most commonly seen in patients with burns or other forms of local skin trauma, although it can also happen in patients who are not immunocompromised. Initial infection causes pus, abscess formation, tissue swelling, and necrosis, as well as an acute inflammatory response. The lesions might be red and indurated, and they frequently turn into black eschars. When a pathogen spreads hematogenously, secondary cutaneous infection occurs; lesions typically begin as an erythematous, painful, and indurated cellulitis and proceed to an ulcer covered in a black eschar.

- *Gastrointestinal mucormycosis:* It is less prevalent than the other clinical types and is thought to be caused by the organism being consumed. It usually affects malnourished people or premature babies. Most typically, the stomach, colon, and ileum are impacted. The most common symptoms include nonspecific abdominal pain and distension, nausea, and vomiting, as well as gastrointestinal bleeding.

- *Disseminated mucormycosis:* It may follow any of the forms of mucormycosis types listed above, but it's most common in neutropenic patients with a lung infection. The brain is the most common location of spread, but it can also affect the spleen, heart, skin, and other organs.

2.2 Diagnosis and treatment:

In this section we will discuss about the potential diagnosis methods and the treatment

- Sample fluid from the respiratory system is collected and sent to a laboratory for different tests.
- Tissue biopsy, in which a small sample of affected tissue is analyzed in a laboratory.
- Imaging tests such as a CT scan, X-ray of lungs, sinuses, or other parts of the body.
- Mucormycosis is a serious infection and needs to be treated with prescription antifungal Medicine.

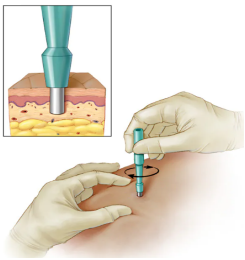

Fig.1: Tissue biopsy; Link

- Often, mucormycosis requires surgery to cut away the infected tissue.
- Usually amphotericin B, posaconazole, or isavuconazole are used.
- These medicines are given through a vein (amphotericin B, posaconazole, isavuconazole) or by mouth (posaconazole, isavuconazole).

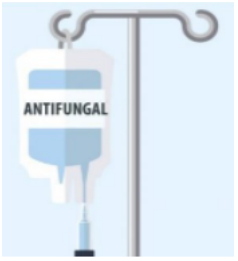

Fig. 2: Antifungal medicine; Link

2.3 Chest x-ray findings:

Now let's see the chest x-ray findings of all categories: Normal, Bacterial Pneumonia, Covid-19, Mucormycosis and compare them. Fig. 3 Demonstrate different colors for different tissues under normal exposure.

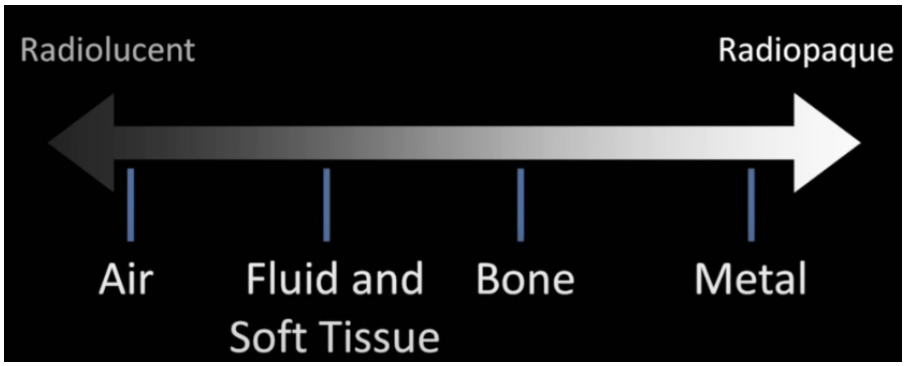

Fig. 3: Demonstration of different colors for different tissues, Source: Link

Normal:

- Ribs are clearly visible,Trachea is straight
- Very clean image, no hazy shadow anywhere.
- Near diaphragm no fluid or any kind of mass
- No consolidations / Nodules / mass anywhere
- Both lower left and right side have clear sharp angles

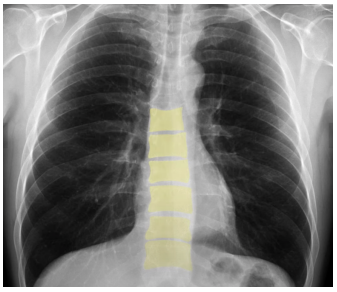

Fig. 4: Normal chest x ray; Source: Link

Pneumonia:

- Fluid gets filled in bronchial tubes.
- Image is hazy, implies consolidation (Mazor imaging feature).
- Other imaging features: Pleural effusion, Lung cavities
- Extent of haziness depends on the extent of pneumonia.
- Can be single lobar or multilobar.
- No nodules or mass anywhere.

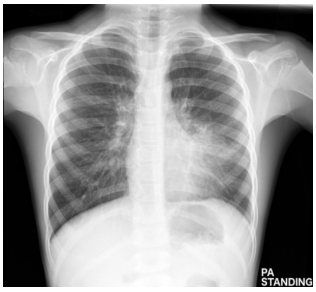

Fig. 5: Pneumonia chest x-ray; Source: Link

COVID-19:

- It's a type of pneumonia, which happens due to CoronaVirus.
- Initial imaging feature: Ground glass opacity.
- Later can turn into consolidation or crazy paving pattern

  (swelling of the interstitial space along the walls of lung lobules).
- Generally multilobar
- No nodules, mass, pleural effusion, or lung cavity.
- Radiological findings can be quite sensitive but are less specific.

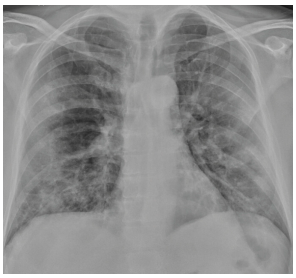

Fig. 6: Covid-19 chest x-ray; Source: Link

Mucormycosis:

- Type of fungal Pneumonia.
- Caused by a group of fungi known as mucormycetes.
- Early imaging may reveal peribronchial ground glass opacity.
- Later can turn into consolidation, nodules, masses and pleural effusion.
- Imaging findings can be non-specific.

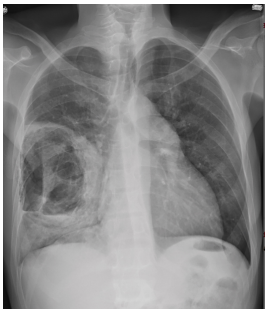

Fig. 7: Mucormycosis chest x-ray; Source: Link

METHODOLOGY

Using image analysis, this study intends to construct an algorithm that can classify pulmonary mucormycosis, COVID-19, and various types of pneumonia. Two freely available datasets are used to do this. Images of normal and pneumonia chest x-rays are included in the first dataset. Images of Pneumonia, COVID-19, and Mucormycosis chest x-rays are included in the second dataset. The data is classified using two Convolution Neural Networks (CNNs) and transfer learning.

3.1 Dataset-1 (Chest x ray images(Pneumonia)):

The dataset for the detection of pneumonia is freely available at 'kaggle'. Here is the link. It contains 2928 chest x-ray images of each category: Pneumonia and Normal. Anterior-posterior chest X-ray images were chosen from retrospective cohorts of children patients aged one to five years old at Guangzhou Women and Children's Medical Center in Guangzhou. All chest X-ray imaging was done as part of the patients' regular medical treatment.

Now as the input data is an image data, we chose to build a Convolution Neural Network (CNN) in order to classify the data as 'Normal' or 'Pneumonia'. The reason for preferring CNN over traditional Artificial Neural Network (ANN) is that CNN works better with the image data. Yann LeCun, a computer scientist, proposed it in the late 1990s, after being inspired by human visual perception of object recognition. The CNN uses a hierarchical model that builds a network, similar to a funnel, and then outputs a fully-connected layer in which all neurons are connected to each other and the output is processed. CNNs are feed forward neural networks that are fully connected. CNNs are exceptionally good at lowering the amount of parameters without sacrificing model quality. Images have a high dimensionality (each pixel is considered a feature), which suits the capabilities of CNNs outlined above. The dimensionality, hence the no. of parameters is reduced in CNN

using a sliding window (filter). The filter moves above the whole image and captures all higher dimensional features and then passes to the next layer and this will continue until all the important features are found. Using these features as input to some dense layers at the ending of CNN, the predictions are made. Fig. 8 shows the working and architecture of a typical CNN.

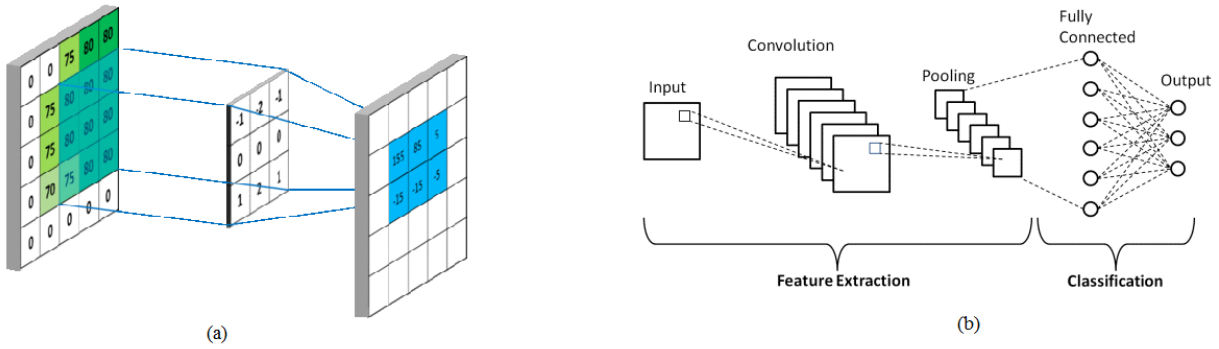

Fig. 8: (a) Working of a typical CNN; Source: Link (b) Architecture of typical CNN; Source: Link

3.2 Architecture of CNN used:

As the x-ray images are a bit complex, to get better predictions a deep CNN is required. This is done using transfer learning, that is a machine learning method where we reuse a pre-trained model as the starting point for a model on a new task. For the classification of x-ray images as Normal or Pneumonia, we used several pre-trained CNN models over 'Imagenet' dataset like VGG-16, VGG-19 and ResNet-50, and it was found that VGG-19 performs the best. Fig. 9 shows the architecture of VGG-19.

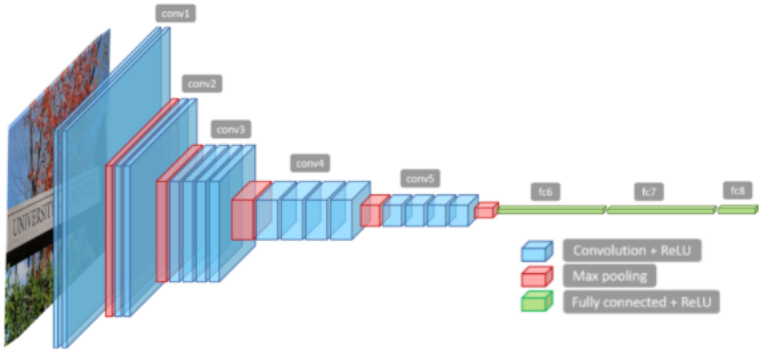

Fig. 9: Architecture of VGG-19; Source: Link

Table 1 shows the architecture of the complete model.

Layer	No. of nodes	Activation	Dropout
Input(120 x 120 x 3)	-	-	-
VGG-19	-	-	-
Dense Layer-1	8	tanh	0.4
Dense Layer-2	8	tanh	0.5
Output	2	softmax	-

Table 1: Architecture of complete model

The dataset was split into training, testing and validation data with test data size and validation data size respectively to be 15% and 10% of the whole dataset. The model was trained on the training dataset with batch size to be 64, no. of epochs to be 130, and optimizer to be 'adadelta' with learning rate of 0.005. The categorical cross entropy was taken as loss, and the accuracy was taken as evaluation metrics.

3.3 Dataset 2 (Chest x ray images (Pneumonia, Covid-19, Mucormycosis)):

The Chest x-ray images of pneumonia and covid are taken from freely available dataset at kaggle. Here is the link. The Chest x ray images of Mucormycosis were taken from google images and the dataset was generated. The final dataset contains chest x-ray images of 4273 x ray images of pneumonia, 576 x ray images of covid, 143 x ray images of mucormycosis. Again as the input data is an image data, we chose to build a Convolution Neural Network (CNN) in order to classify the data as 'Pneumonia' or 'Covid-19' or 'Mucormycosis'. Again the transfer learning is used and this time ResNet-50 was performing better.

3.4 Architecture of CNN used:

Fig. 10 shows the architecture of ResNet-50.

Fig. 10: Architecture of ResNet-50; Source: Link

Table 2 shows the architecture of the complete model.

Layer	No. of nodes	Activation	Dropout
Input(120 x 120 x 3)	-	-	-
ResNet-50	-	-	-
Dense Layer-1	16	tanh	0.3
Dense Layer-2	16	tanh	0.4
Output	3	softmax	-

Table 2: Architecture of complete model

The dataset was split into training, testing and validation data with test data size and validation data size respectively to be 15% and 10% of the whole dataset. The model was trained on the training dataset with batch size to be 64, no. of epochs to be 500, and optimizer to be 'adadelta' with learning rate of 0.004. The categorical

cross entropy was taken as loss, and the accuracy was taken as evaluation metrics. Due to imbalance in classes, the class weights were given while training the model as- Pneumonia: 1.00, Covid: 8.00, Mucormycosis: 32.00.

3.5 Final Algorithm:

Fig. 11 shows the final algorithm. In order to classify an image as one of the four categories, the image will be evaluated from model-1; if it is classified as Pneumonia then it will be evaluated from model-2, where it will be classified as one of the three categories: Pneumonia, Covid-19, Mucormycosis.

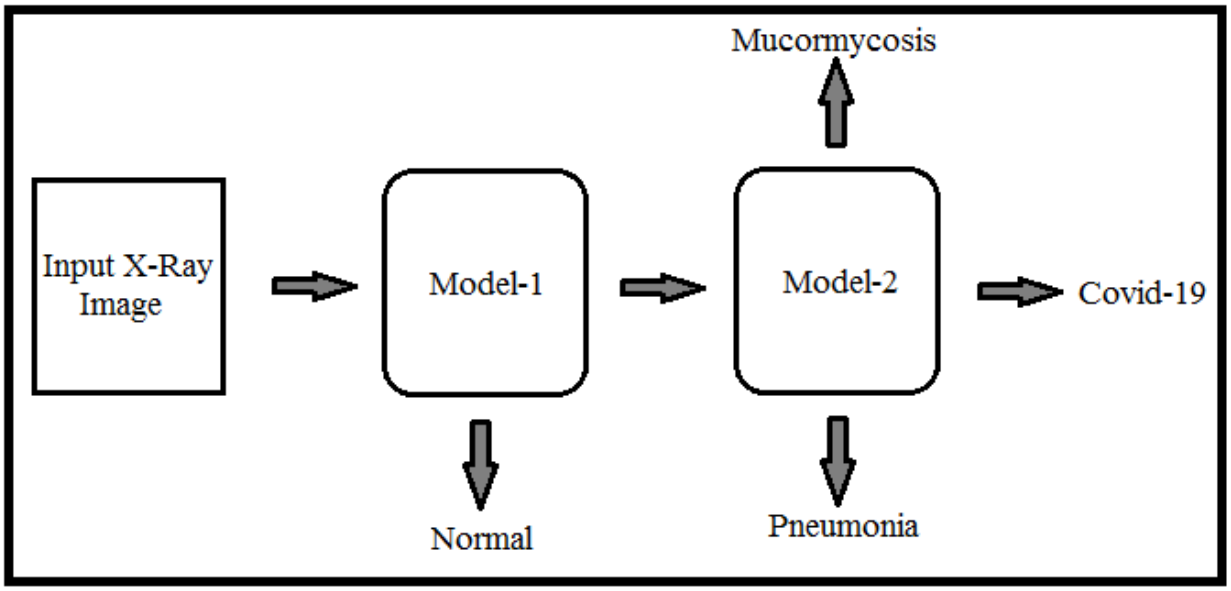

Fig. 11: Final algorithm

RESULTS & DISCUSSION

Two deep Convolutional Neural Networks (CNN) are used for classification of a chest x-ray image as one of the following categories: Normal, Pneumonia, COVID-19, Mucormycosis. The first model is used to classify the image as either Normal or Pneumonia. The second model classifies the image as one of the following: Pneumonia, COVID-19, Mucormycosis. Accuracy and Confusion matrices are used as evaluation metrics.

4.1 Model-1:

Categorical cross entropy is taken as the loss. Fig 12 shows the trends of loss v/s no. of epochs and accuracy v/s no. of epochs for both the training and testing sets.

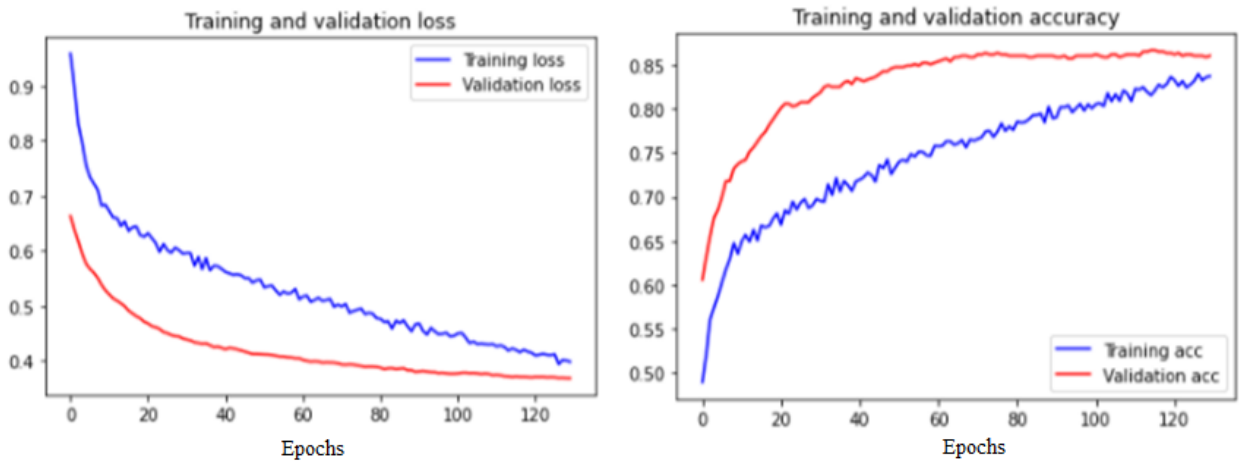

Fig. 12: Training and validation loss vs no. of epochs; Training and validation accuracy vs no. of epochs

The training and testing set accuracy of the model are 93.15% and 95.80% respectively.

Fig. 13 shows confusion matrix for the model. From this matrix, Precision, Recall and F1-score can be calculated; and are shown in table 3

Misclassification	0.04
Sensitivity / Recall	0.93
Precision	0.99
F1-score	0.96

Table 3

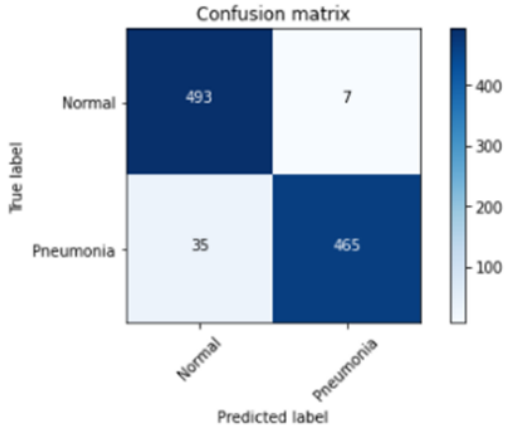

Fig. 13: Confusion matrix for model-1

Precision: As the name suggest, it is the measure of precision of a model and is calculated as $\frac{True\ Positive}{True\ Positive + False\ Positive}$

Recall: It is the measure of sensitivity of a model and is calculated as $\frac{True\ Positive}{True\ Positive + False\ Negative}$

F1-score: It is the harmonic mean of Precision and Recall.

4.2 Model-2:

Categorical cross entropy is taken as the loss. Fig 14 shows the trends of loss v/s no. of epochs and accuracy v/s no. of epochs for both the training and testing sets.

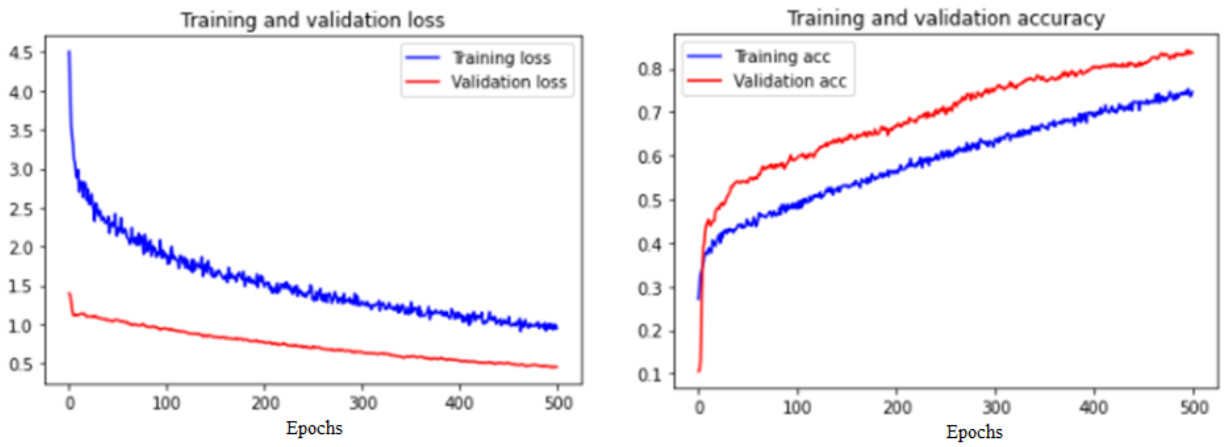

Fig. 14: Training and validation loss vs no. of epochs; Training and validation accuracy vs no. of epochs

The training and testing set accuracy of the model are 88.85% and 92.07% respectively.

Fig. 15 shows confusion matrix for the model. From this matrix, Precision, Recall and F1-score can be calculated; and are shown in table 4

	Precision	Recall	F1-score
Pneumonia	0.99	0.93	0.96
Covid-19	0.81	0.93	0.87
Mucormycosis	0.45	0.66	0.54

Table 4

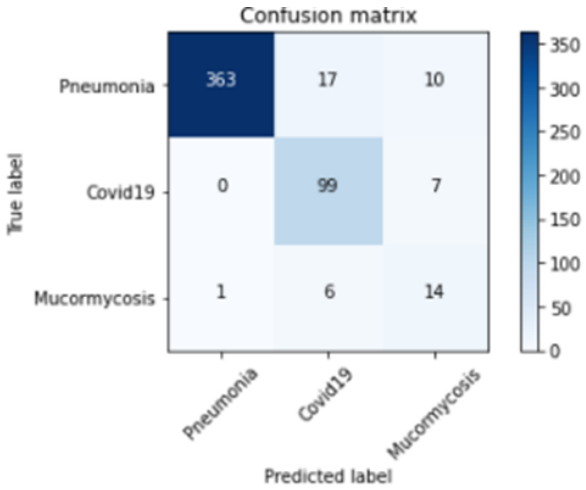

Fig. 15: Confusion matrix for model-2

CONCLUSION

The objective of the study is to develop an algorithm that can classify Pulmonary mucormycosis, COVID-19, and different kinds of pneumonia using image analysis. In this article we have discussed Mucormycosis and its types: Rhinocerebral, Pulmonary, Cutaneous, Gastrointestinal, Disseminated. Then their symptoms, potential diagnosis methods and treatment. The diagnosis includes imaging tests such as CT scan, X-ray of lungs, sinuses, Tissue biopsy. Further we discussed the demonstration of different colors for different tissues in normal chest x-ray and the chest x-ray findings of all the categories: Pulmonary mucormycosis, Pneumonia, COVID-19, Normal. In Pulmonary mucormycosis, there can be nodules, masses, pleural effusion along with the consolidation; In COVID-19, in general there will be multilobar consolidation with no nodules, masses or pleural effusion; In Pneumonia, there will be consolidation as a mazor imaging feature along with lung cavities and pleural effusion. Further, in order to classify the chest x-ray image, we used two datasets. The first dataset contains images of Pneumonia and Normal chest x-ray. A deep CNN with the help of transfer learning is used to classify this data. VGG-19 as a pre-trained model is selected. The architecture of the complete model is shown in section 3.2. The model attains a training set accuracy of 93.15% and test set accuracy of 95.80%. The confusion matrix for the model is shown in section 4.1. The second dataset contains images of Pneumonia, COVID-19, Mucormycosis chest x-ray. Again a deep CNN with the help of transfer learning is used to classify this data. ResNet-50 as a pre-trained model is selected. The architecture of the complete model is shown in section 3.4. The model attains a training set accuracy of 88.85% and test set accuracy of 92.07%. The confusion matrix for the model is shown in section 4.2. The final algorithm is shown in section 3.5; where the input image first gets evaluated by model-1, if classified as pneumonia then it gets evaluated by model-2 where it is classified as Pneumonia or COVID-19 or Mucormycosis.

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