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Dataset:

https://drive.google.com/drive/u/1/folders/1-FzZhQO9oHIT9SNOWYoKsuz7fe447vtR

GitHub link:

https://github.com/Basir-mahmood/msds19043_COVID19_DLSpring2020

INTRODUCTION:

The assignment includes the classification of X-Ray Images and the classes are for the COVID-19 infected or normal. VGG16 and RESNET-18 are used for the detection and classification of the images. There are several analyses which are given in the following. The most significant problem faced was the time constraint, time to complete and submit within deadline is too near, whereas, each epoch takes around 6 minutes approximately. So, in the whole a lot of time is required for analysis.

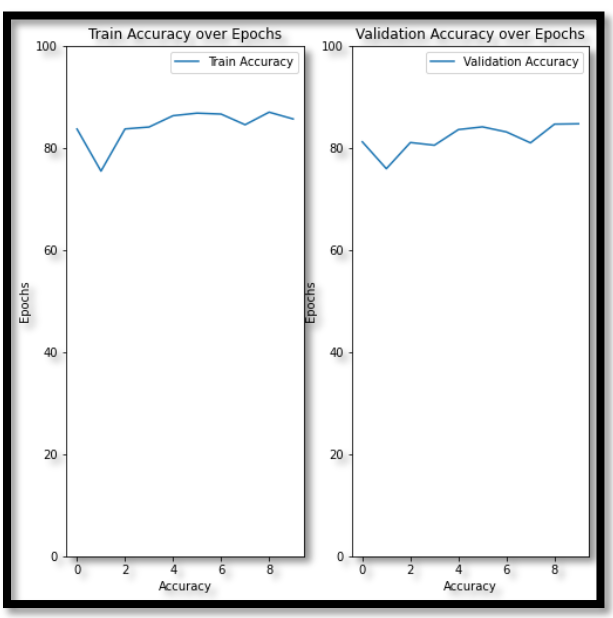
EXPERIMENTAL SETUP:

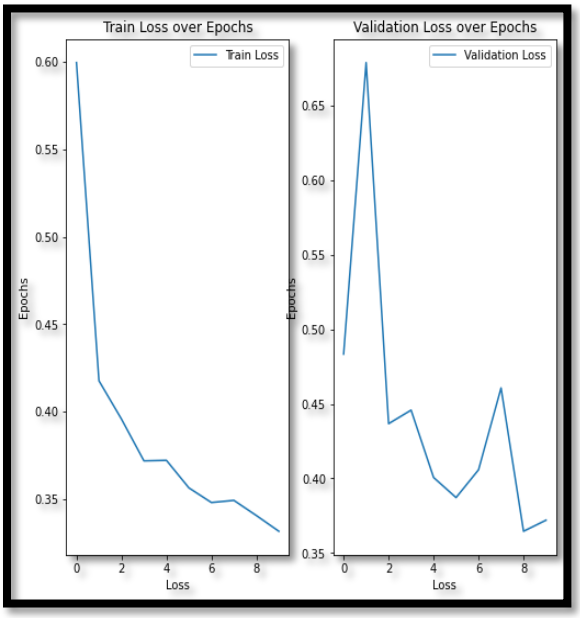
TASK 1:

I. VGG16 FCLayer530, learning rate 0.001

In the first task, the vgg16 network's FC layer was changed, where the first layer's neuron was changed to 530, which is equal to = (roll number*10)+100, and there is a second layer with two neurons i.e., number of classes . The accuracy over the epochs can be seen in the following image.

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	3701	1218
Actual Normal	295	5503

F1 Score is : 0.879

Accuracy : 85.88

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	445	170
Actual Normal	81	804

F1 Score is : 0.864

Accuracy : 83.26

Testing

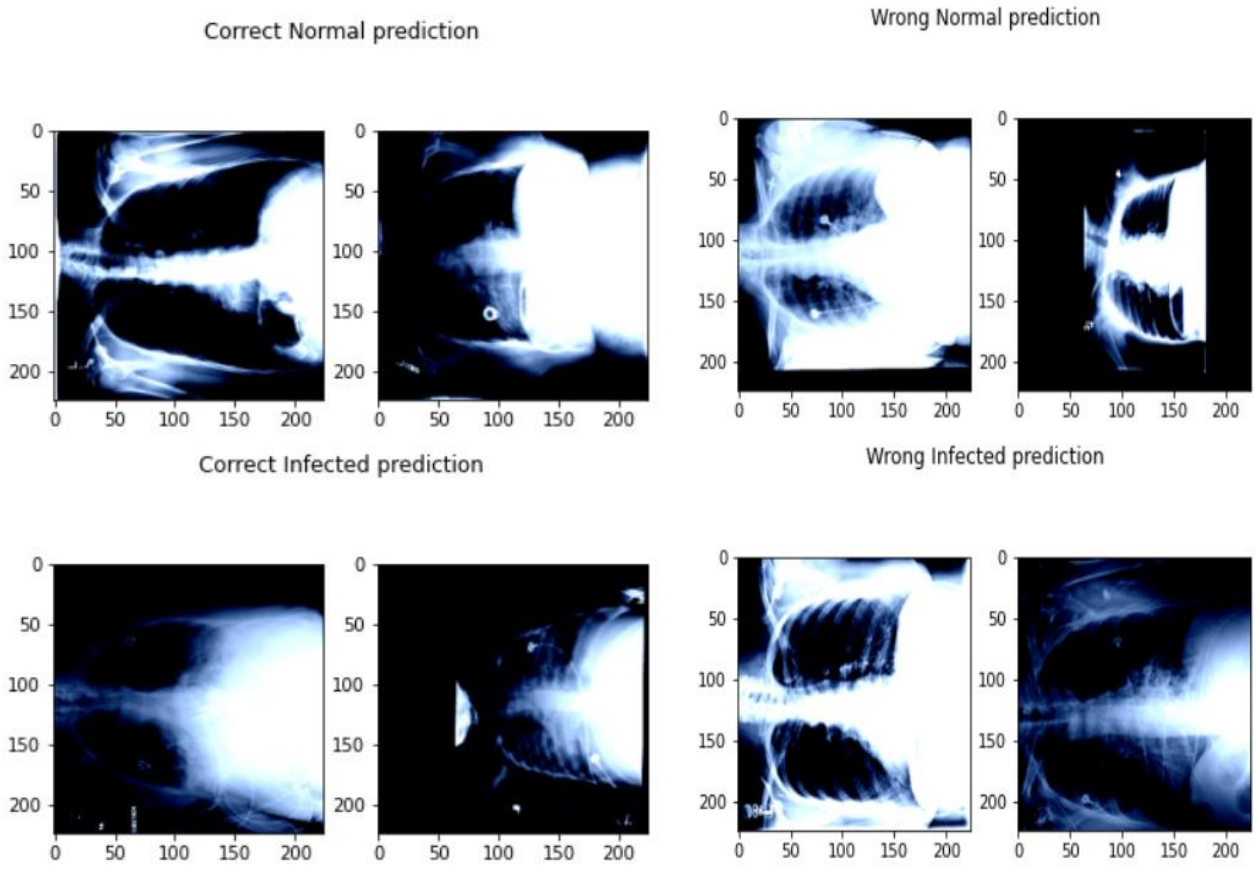
Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	474	141
Actual Normal	8	877

F1 Score is : 0.921

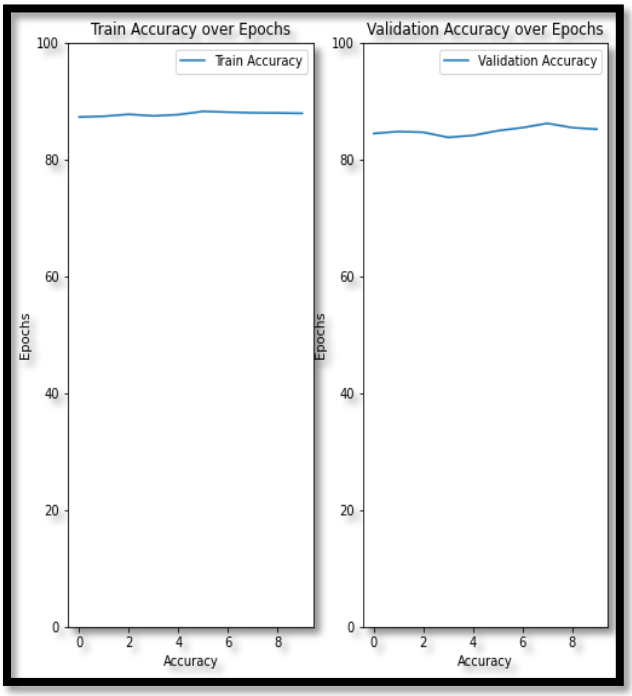
Accuracy : 90.06

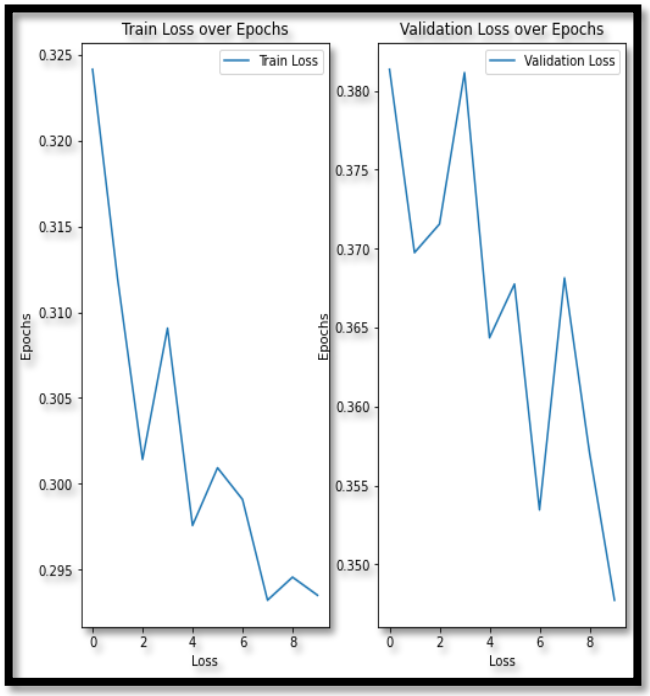
Following are the two sample images from each class results.



II. VGG16 FCLayer530, learning rate 0.00001

In this part, learning rate is changed to 0.00001, and the other parameters are same.





Following are the Accuracy, F1 Measure and Confusion Matrices.

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4185	734
Actual Normal	498	5300

F1 Score is : 0.895

Accuracy : 88.50

Testing

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	544	71
Actual Normal	25	860

F1 Score is : 0.947

Accuracy : 93.60

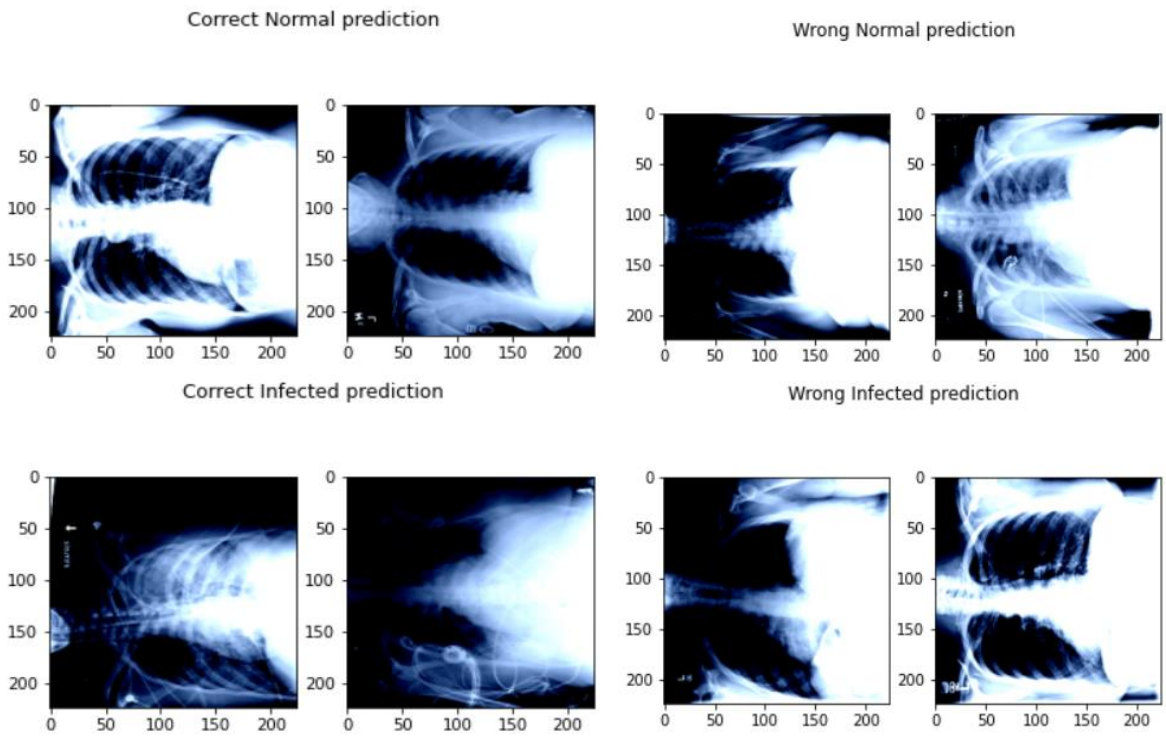
Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	518	97
Actual Normal	109	776

F1 Score is : 0.882

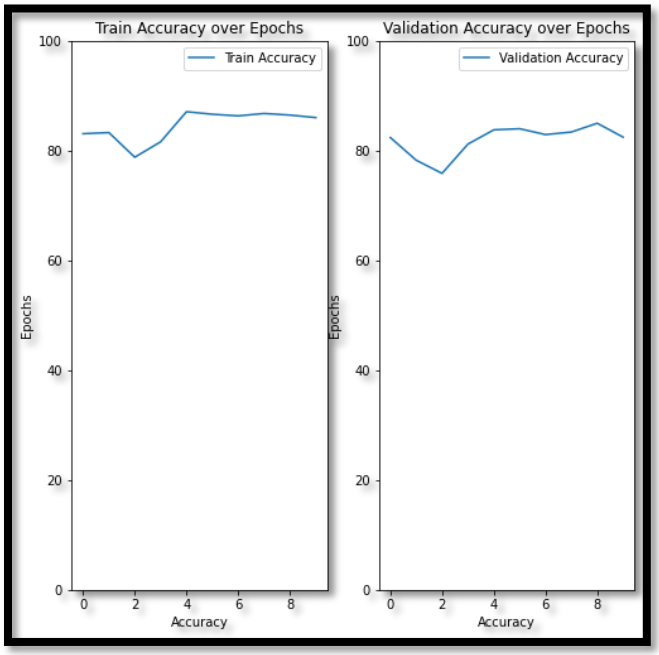
Accuracy : 86.26

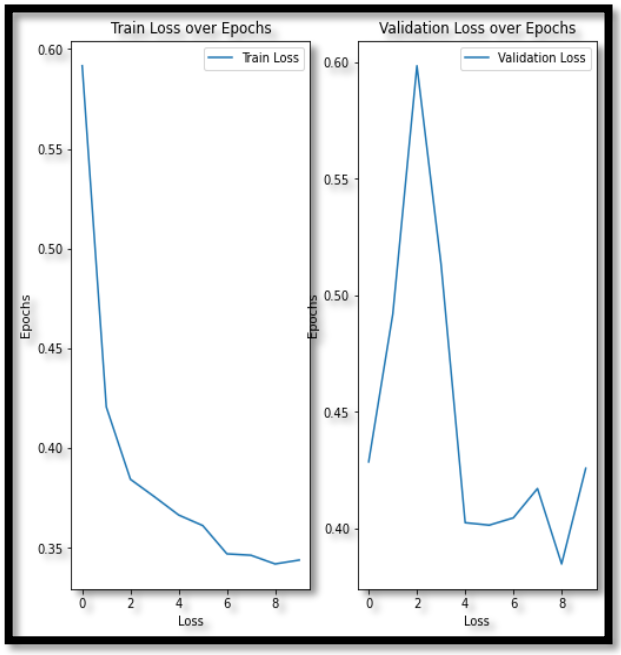


Above given are the 2 images from each result class predictions

III. VGG16 FCLayer 2000, learning rate 0.001

Following are the loss and accuracy curves obtained over epochs.





F1- measure, Accuracy and Confusion Matrices are as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4339	580
Actual Normal	942	4856

F1 Score is : 0.864

Accuracy : 85.79

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	538	77
Actual Normal	177	708

F1 Score is : 0.847

Accuracy : 83.06

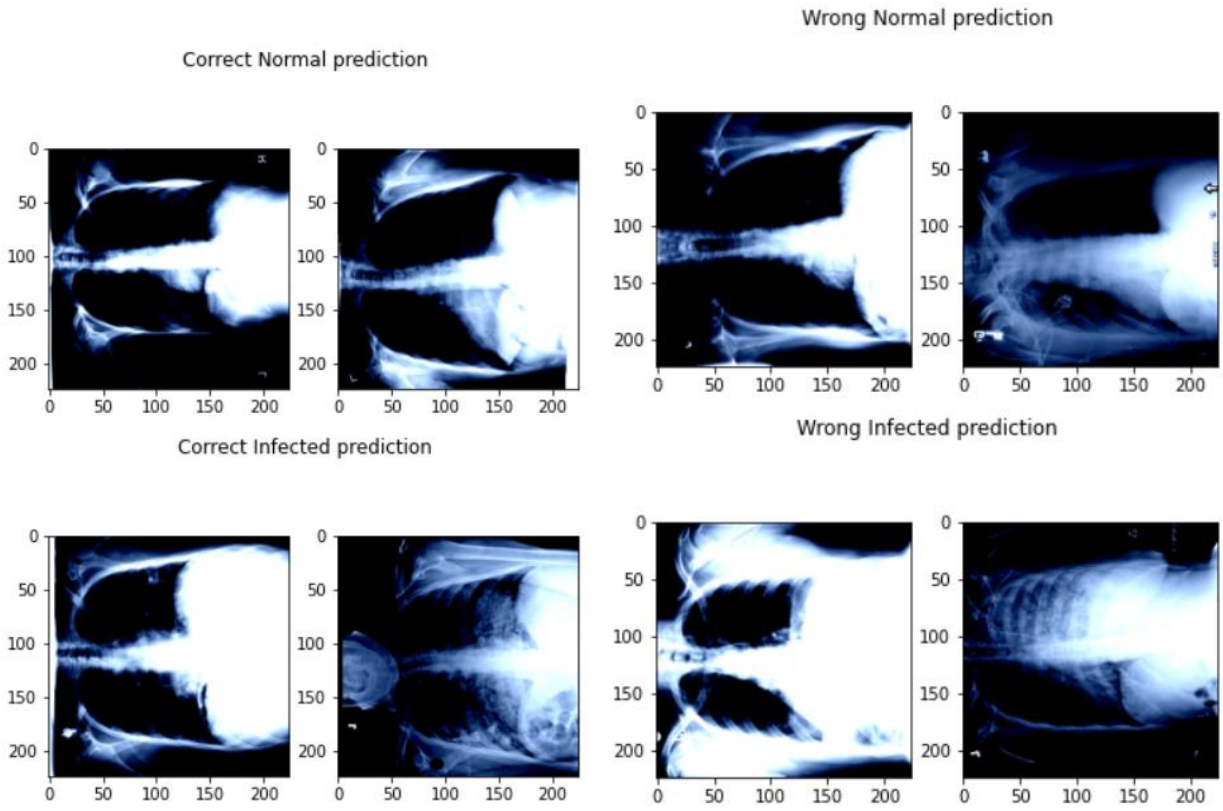
Testing

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	565	50
Actual Normal	48	837

F1 Score is : 0.944

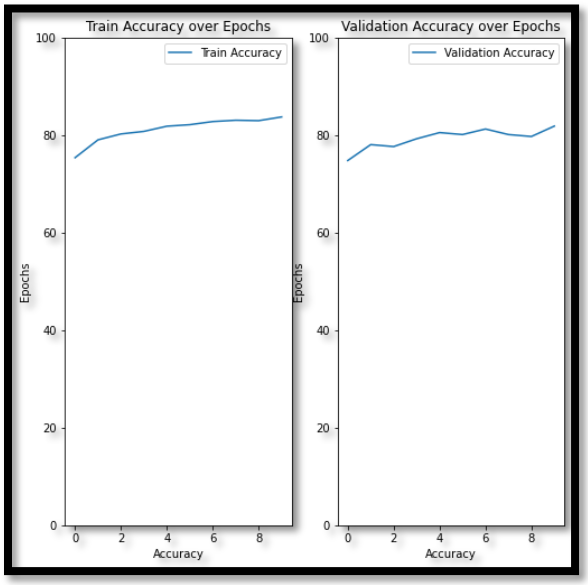
Accuracy : 93.46

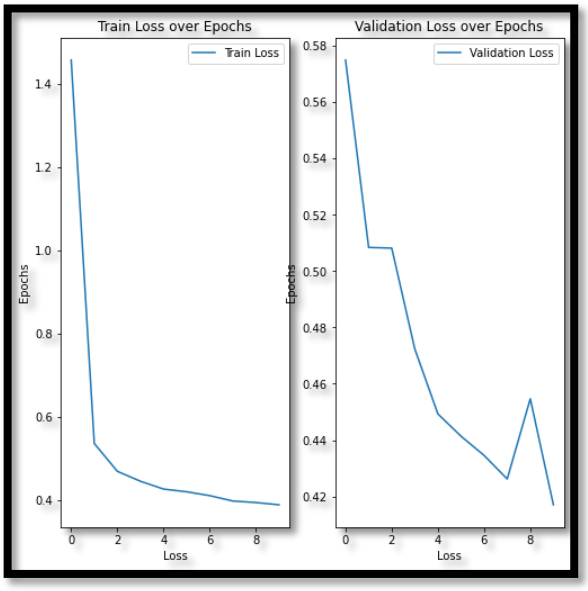


Above are the 2 case examples for each resultant of class.

IV. VGG16 FCLayer: 2000 , learning rate 0.00001

FC Layers neurons are changed from 530 to 2000. Following results are obtained.





Accuracy, F1- Measure and Confusion Matrices are following

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	3793	1126
Actual Normal	694	5854

F1 Score is : 0.865

Accuracy : 84.12

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	481	134
Actual Normal	116	769

F1 Score is : 0.860

Accuracy : 83.33

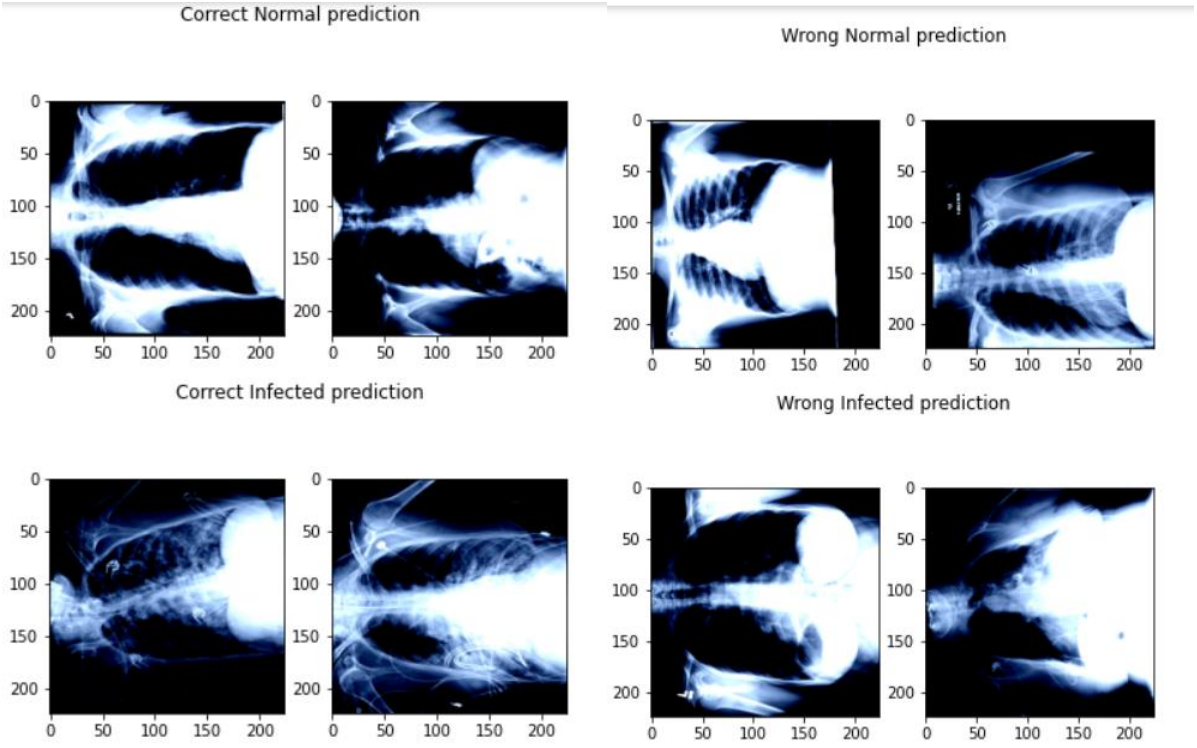
Testing

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	517	98
Actual Normal	37	848

F1 Score is : 0.926

Accuracy : 91.0

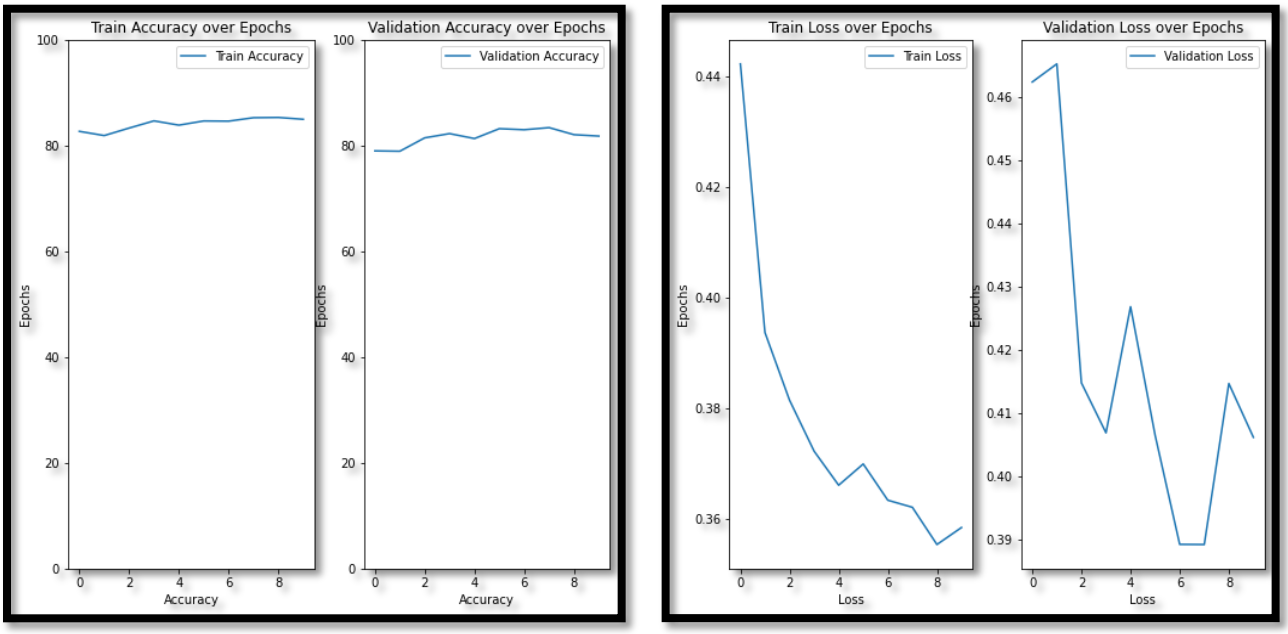


Above given are the 2 pictures for each case.

V. RESNET FCLayer530, learning rate 0.001

In this task, the ResNet network's FC layer was changed, where the first layer's neuron was changed to 530, which is equal to = (roll number*10)+100, and there is a second layer with two neurons i.e., number of classes . The accuracy over the epochs can be seen in the following image.

Following graphs, describe the losses and training curves over epochs.



Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4149	770
Actual Normal	897	5188

F1 Score is : 0.861

Accuracy : 84.85

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	528	87
Actual Normal	172	713

F1 Score is : 0.846

Accuracy : 82.73

Testing

Confusion Matrix

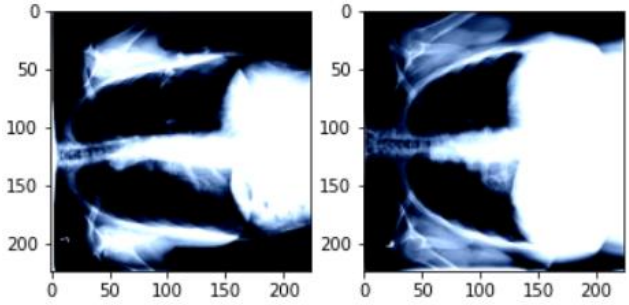
	Predicted Infected	Predicted Normal
Actual Infected	562	53
Actual Normal	171	714

F1 Score is : 0.864

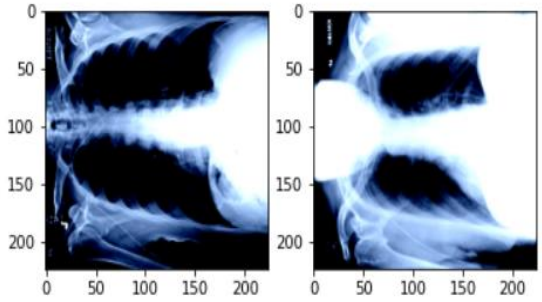
Accuracy : 85.06

Following are the two sample images from each class results.

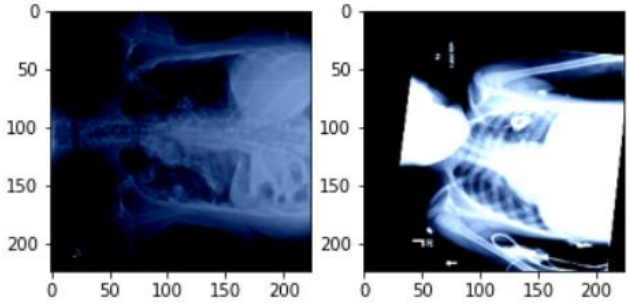
Correct Normal prediction



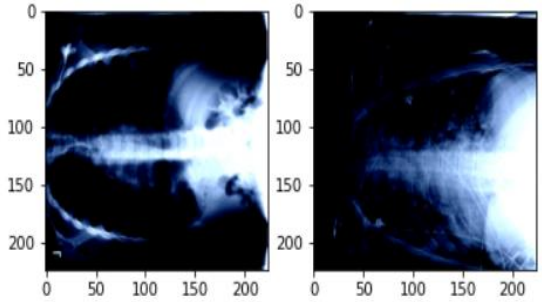
Wrong Normal prediction



Correct Infected prediction



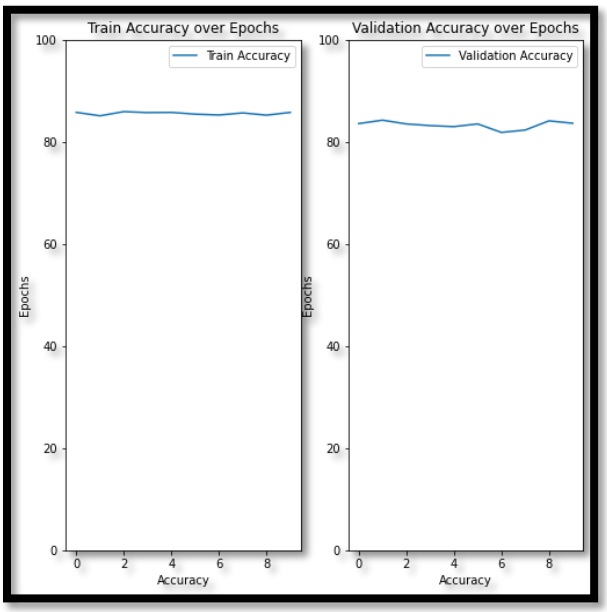
Wrong Infected prediction

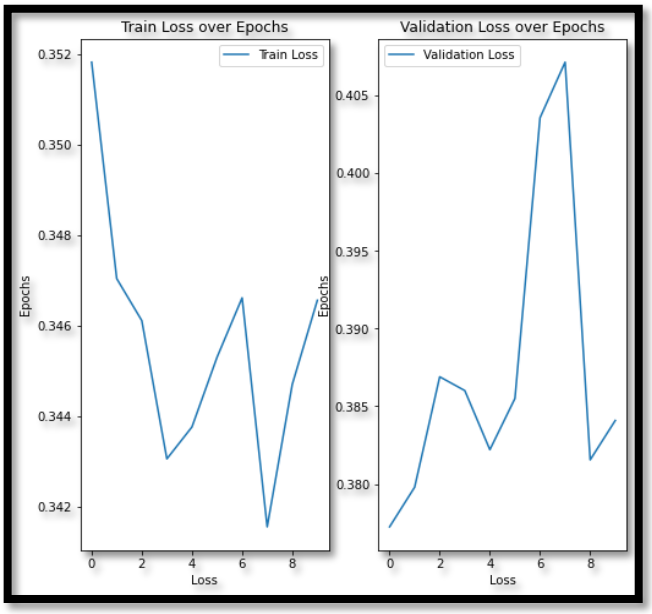


VI. RESNET FCLayer530, learning rate 0.00001

In this task, the resNet network's FC layer was changed, where the first layer's neuron was changed to 530, which is equal to = (roll number*10)+100, and there is a second layer with two neurons i.e., number of classes . The accuracy over the epochs can be seen in the following image.

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	3990	929
Actual Normal	675	5410

F1 Score is : 0.870

Accuracy : 85.42

Testing

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	539	76
Actual Normal	121	764

F1 Score is : 0.885

Accuracy : 86.86

Validation

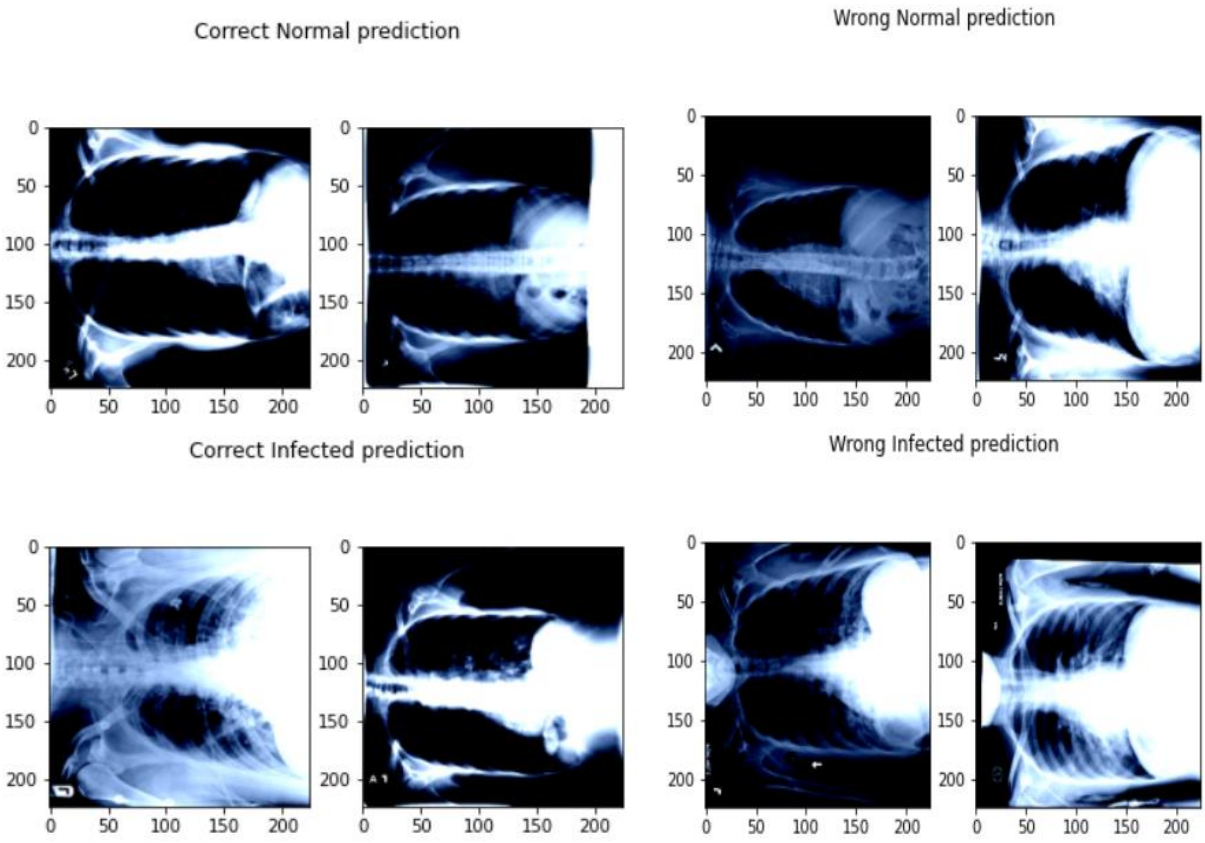
Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	486	129
Actual Normal	129	756

F1 Score is : 0.854

Accuracy : 82.8

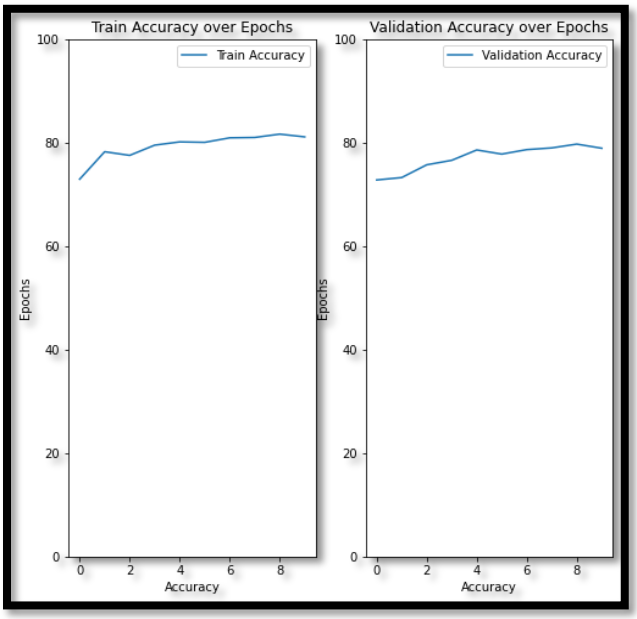
Following are the two sample images from each class results.

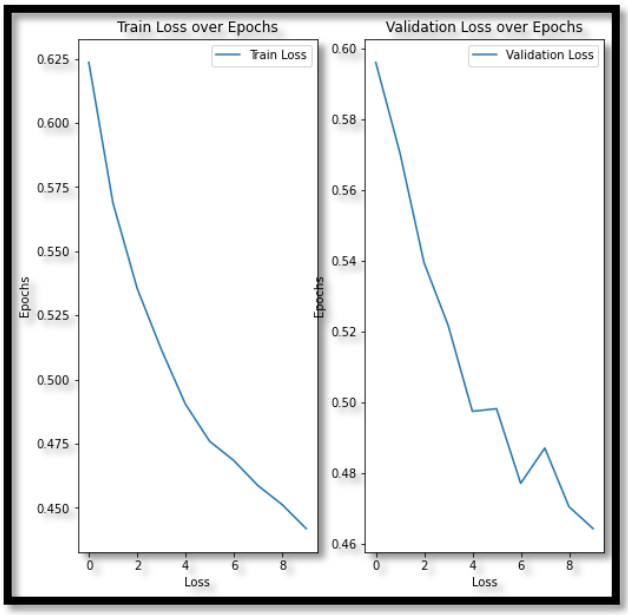


VII. RESNET FCLayer 2000, learning rate 0.00001

In this task, the resNet network's FC layer was changed, where the first layer's neuron was changed to 200, and there is a second layer with two neurons i.e., number of classes . The accuracy over the epochs can be seen in the following image.

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	3633	1286
Actual Normal	830	5718

F1 Score is : 0.843

Accuracy : 81.54

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	438	177
Actual Normal	136	749

F1 Score is : 0.827

Accuracy : 79.13

Testing

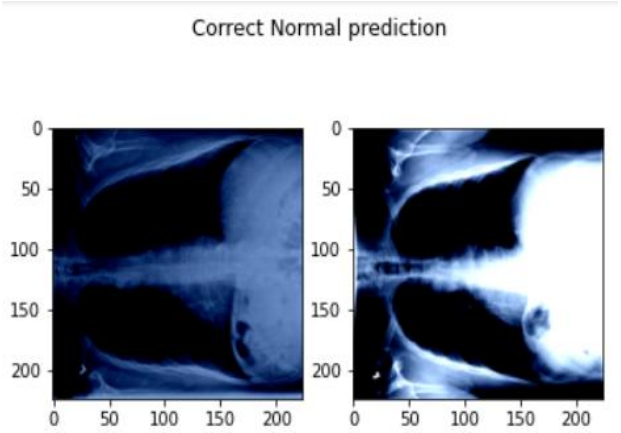
Confusion Matrix

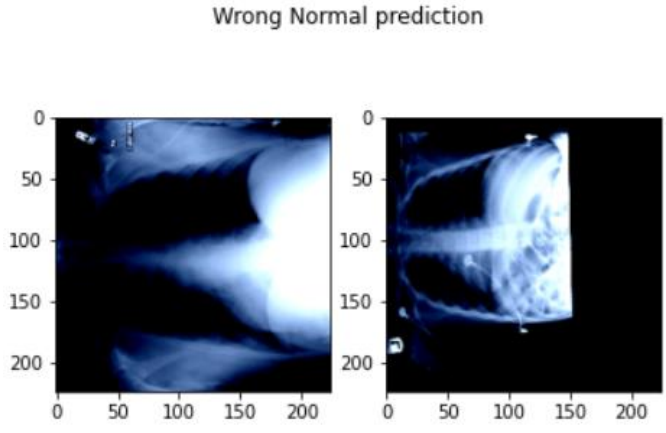
	Predicted Infected	Predicted Normal
Actual Infected	483	132
Actual Normal	89	796

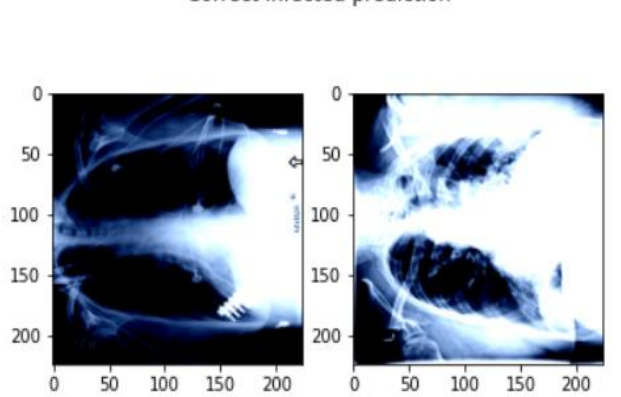
F1 Score is : 0.878

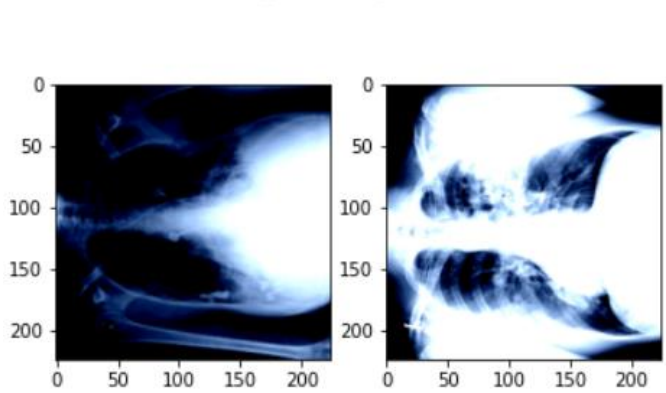
Accuracy : 85.26

Following are the two sample images from each class results.







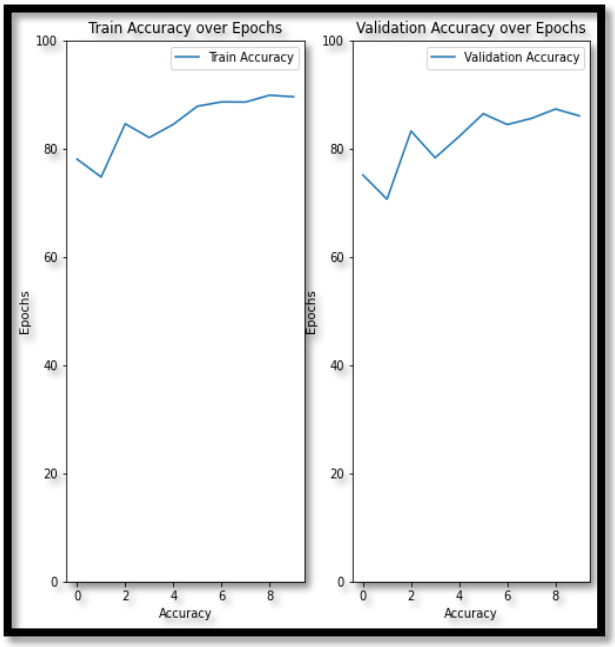


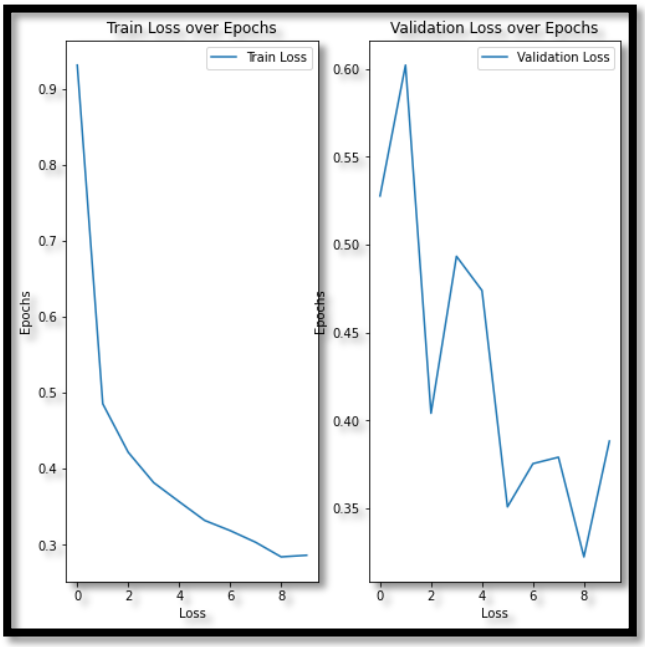
TASK 2

I. VGG Net, learning rate 0.001

In this task, the VGG network's is trained on the data,

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4347	572
Actual Normal	610	5938

F1 Score is : 0.909

Accuracy : 89.69

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	536	79
Actual Normal	122	763

F1 Score is : 0.883

Accuracy : 86.6

Testing

Confusion Matrix

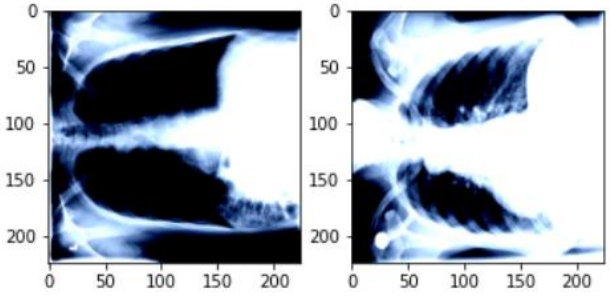
	Predicted Infected	Predicted Normal
Actual Infected	584	31
Actual Normal	29	856

F1 Score is : 0.966

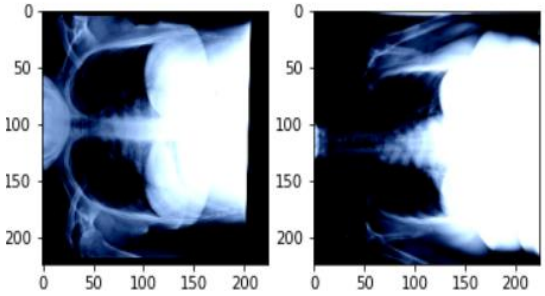
Accuracy : 96.0

Following are the two sample images from each class results.

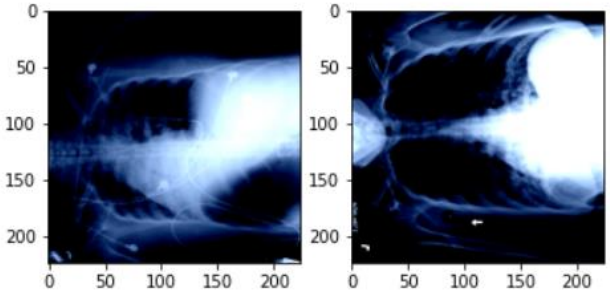
Correct Normal prediction



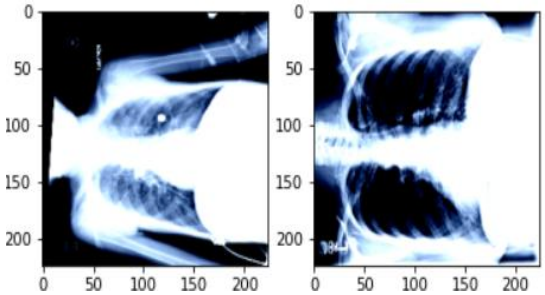
Wrong Normal prediction



Correct Infected prediction



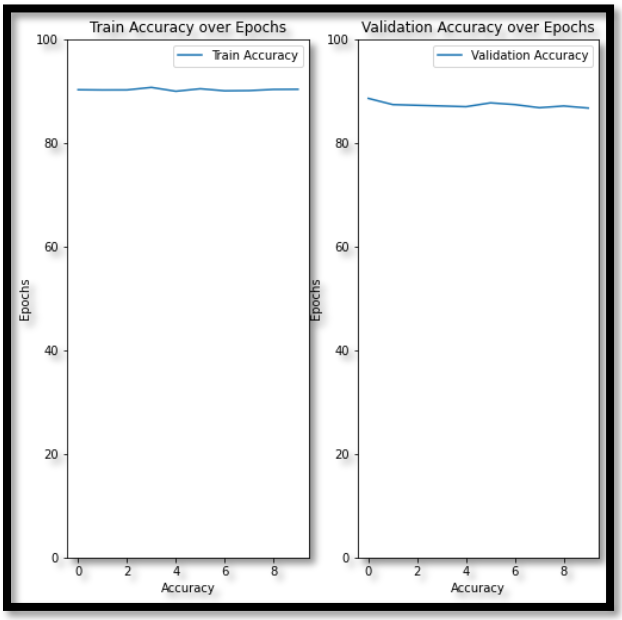
Wrong Infected prediction

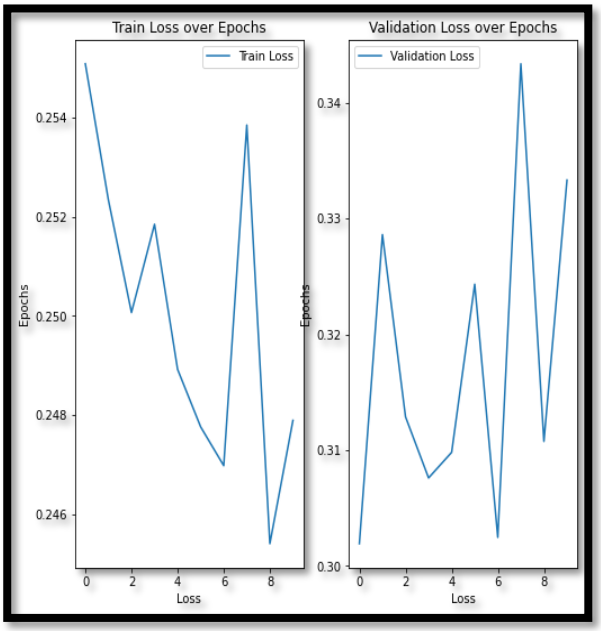


II. VGG Net 16, convolutional layers FREEZED, learning rate 0.001

In this task, the VGG network's is trained on the data,

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4173	746
Actual Normal	376	6172

F1 Score is : 0.916

Accuracy : 90.21

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	518	97
Actual Normal	74	811

F1 Score is : 0.904

Accuracy : 88.6

Testing

Confusion Matrix

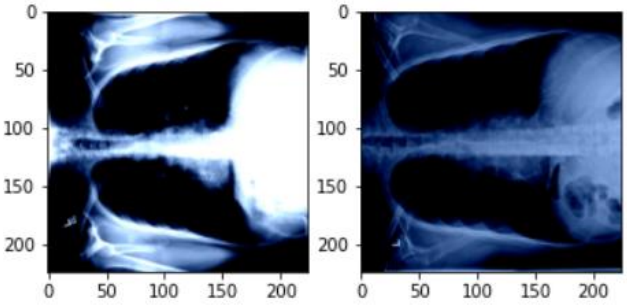
	Predicted Infected	Predicted Normal
Actual Infected	573	42
Actual Normal	9	876

F1 Score is : 0.971

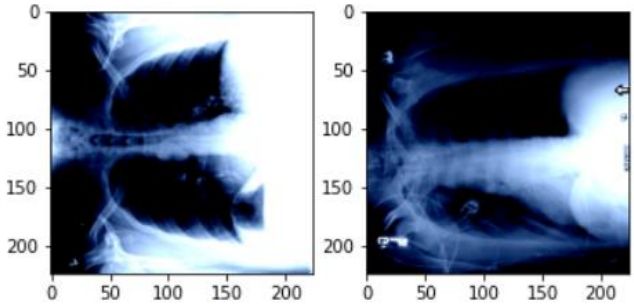
Accuracy : 96.6

Following are the two sample images from each class results.

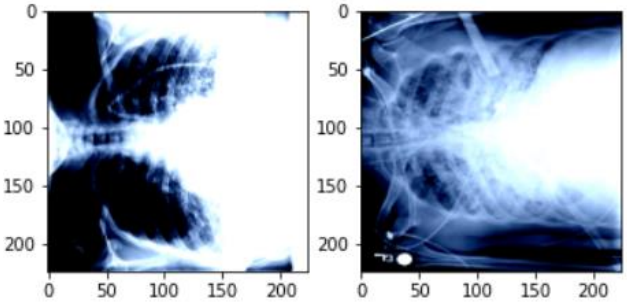
Correct Normal prediction



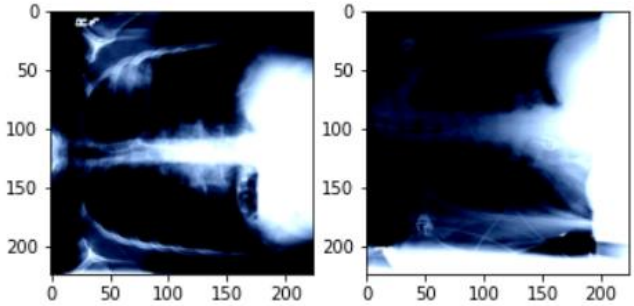
Wrong Normal prediction



Correct Infected prediction



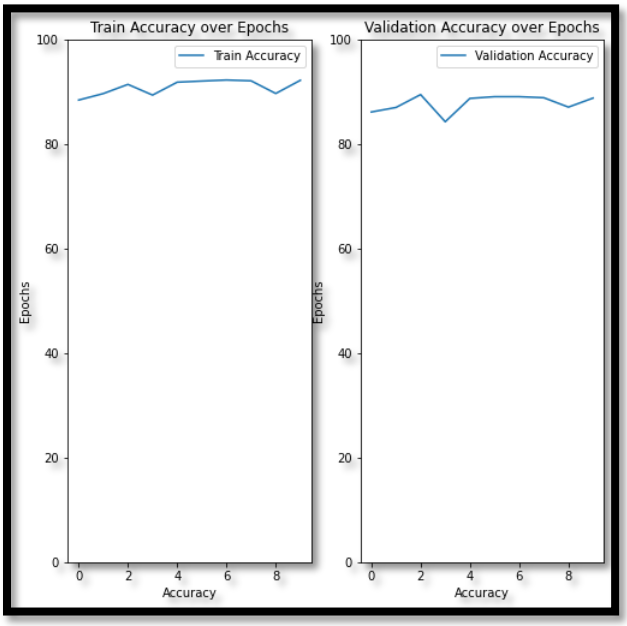
Wrong Infected prediction

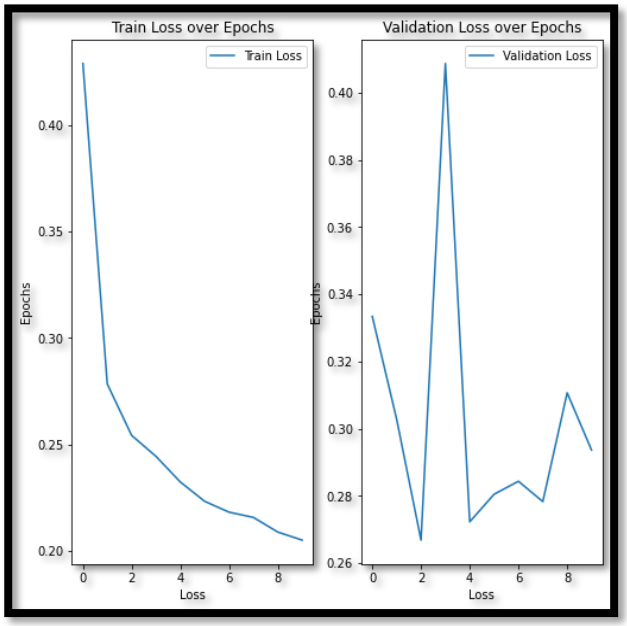


III. VGG Net 16, convolutional layers freezed [0,2,5,10,24,28], learning rate 0.001

In this task, the VGG network's is trained on the data,

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4510	409
Actual Normal	503	6045

F1 Score is : 0.929

Accuracy : 92.04

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	561	54
Actual Normal	95	790

F1 Score is : 0.913

Accuracy : 90.06

Testing

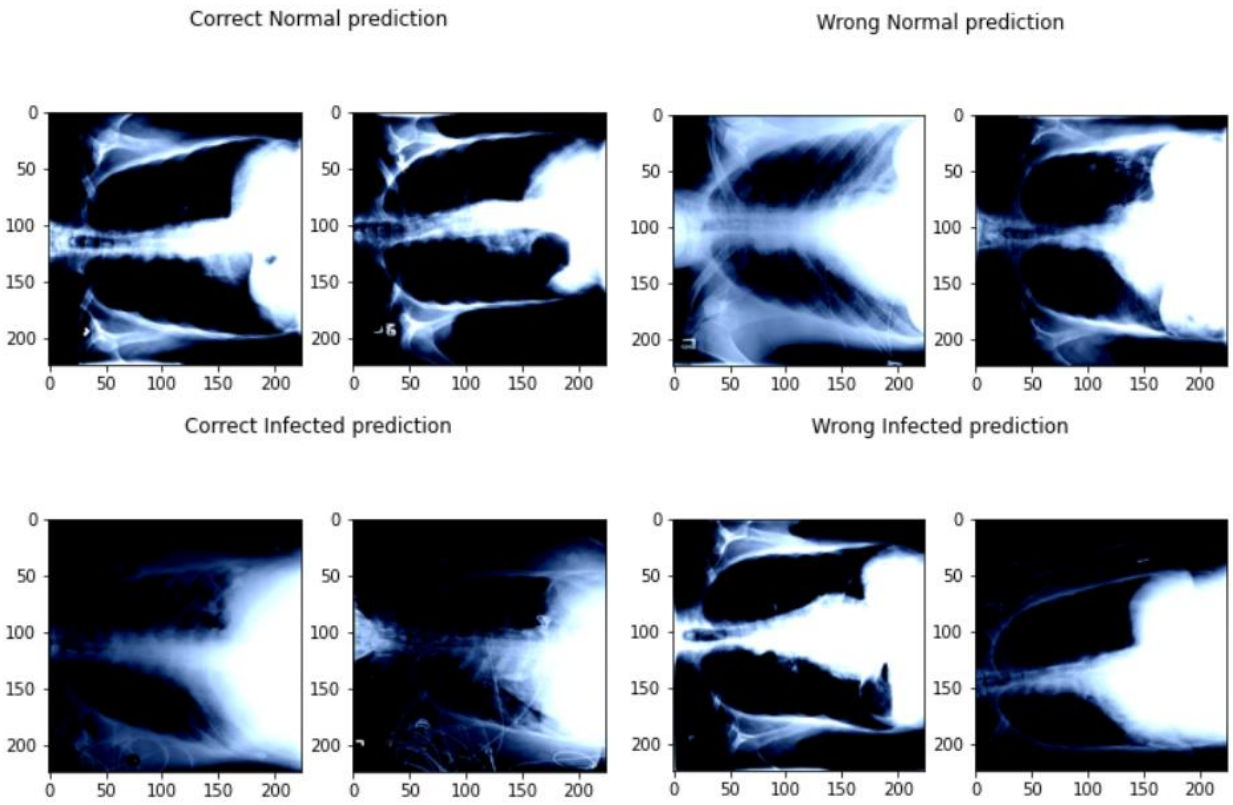
Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	589	26
Actual Normal	17	868

F1 Score is : 0.975

Accuracy : 97.13

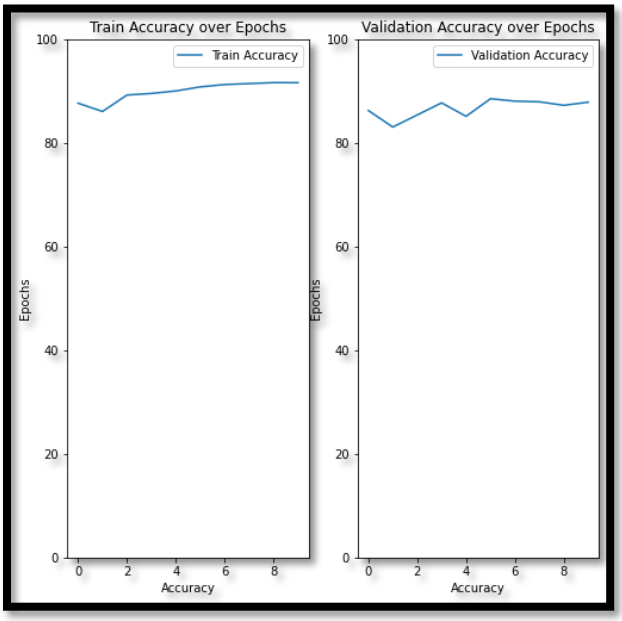
Following are the two sample images from each class results.

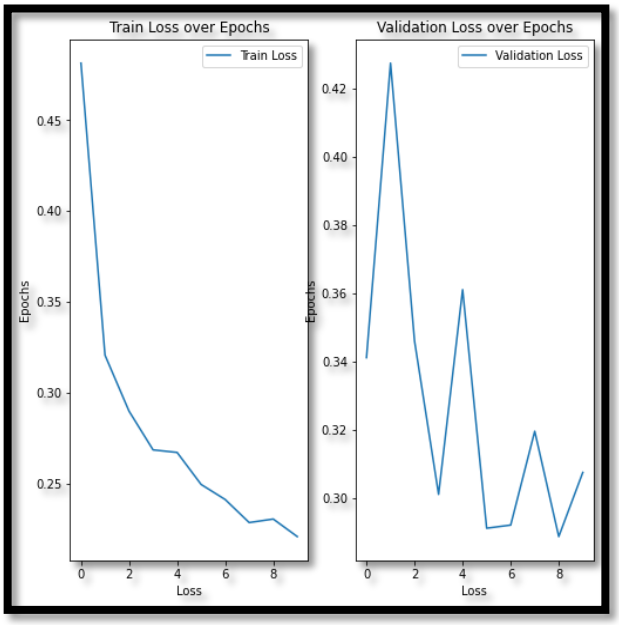


IV. Res Net 18, No Freezing learning rate 0.001

In this task, the VGG network's is trained on the data,

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4453	466
Actual Normal	484	6064

F1 Score is : 0.927

Accuracy : 91.71

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	552	63
Actual Normal	101	784

F1 Score is : 0.905

Accuracy : 89.06

Testing

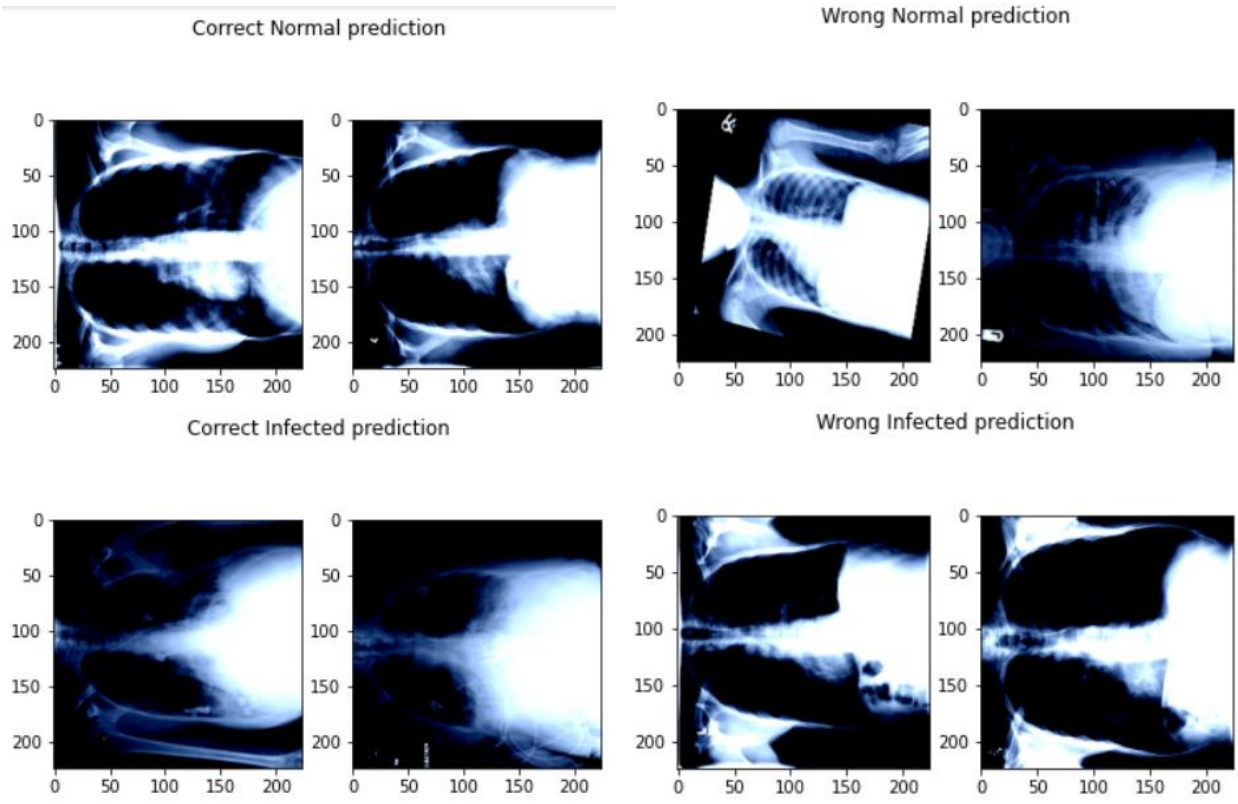
Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	595	20
Actual Normal	30	855

F1 Score is : 0.971

Accuracy : 96.66

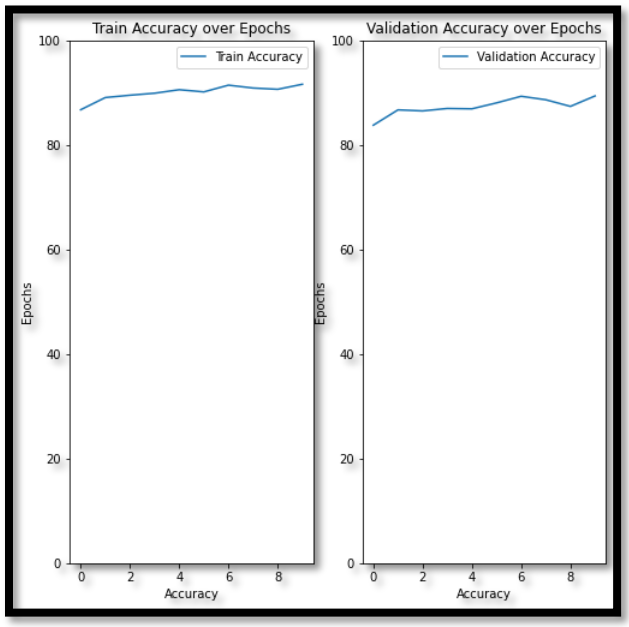
Following are the two sample images from each class results.

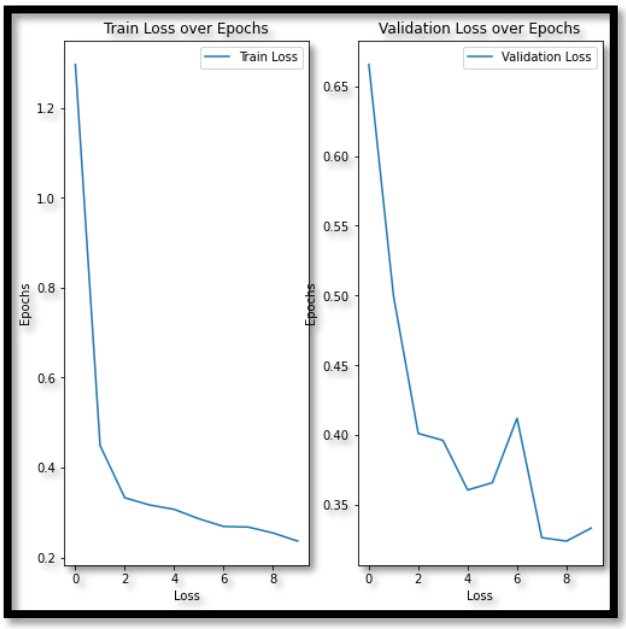


V. Res Net 18, FC layers freeze, learning rate 0.001

In this task, the VGG network's is trained on the data,

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4181	738
Actual Normal	230	6318

F1 Score is : 0.928

Accuracy : 91.55

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	495	120
Actual Normal	64	821

F1 Score is : 0.899

Accuracy : 87.73

Testing

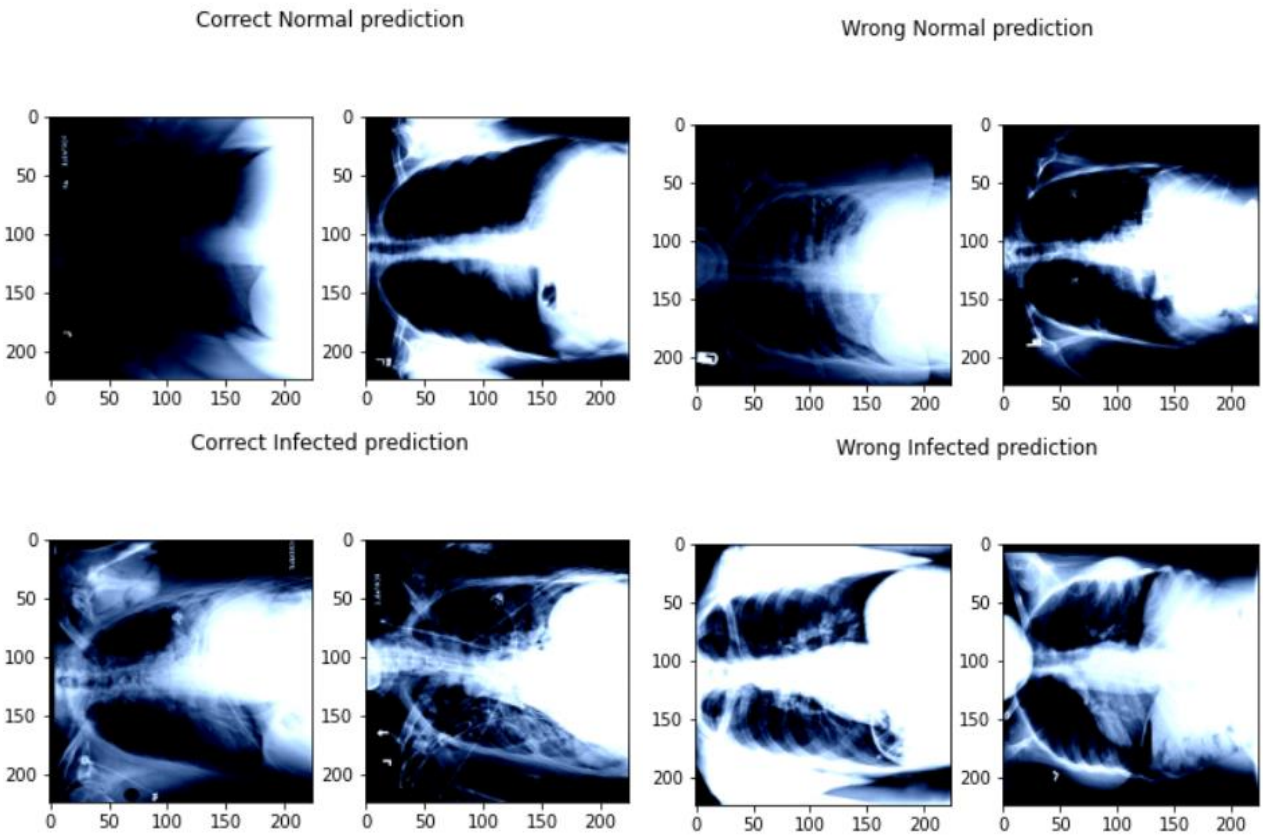
Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	581	34
Actual Normal	14	871

F1 Score is : 0.973

Accuracy : 96.8

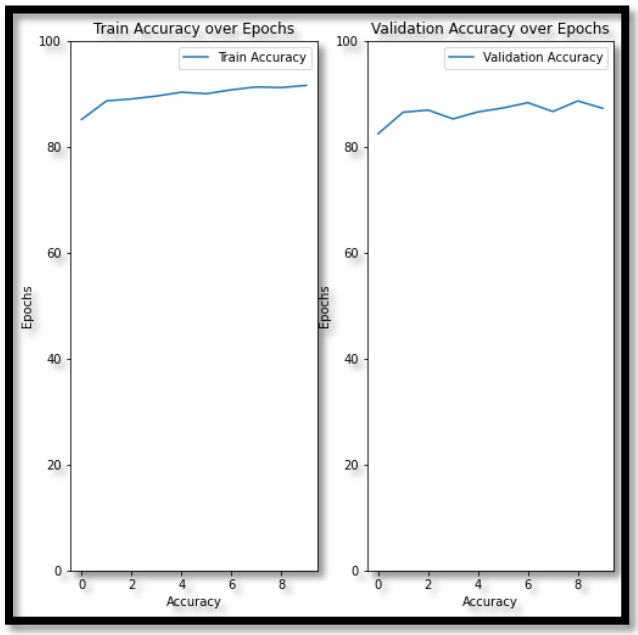
Following are the two sample images from each class results.

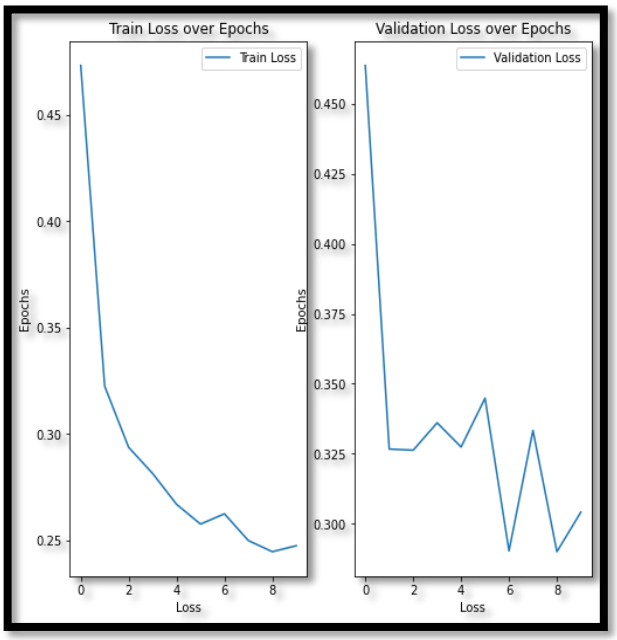


VI. Res Net 18,convolution 1 and 2 layers freeze, learning rate 0.001

In this task, the VGG network's is trained on the data,

Following graphs, describe the losses and training curves over epochs.





Accuracy, F1 measure and confusion matrix is as follows,

Training

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	4368	551
Actual Normal	435	6113

F1 Score is : 0.925

Accuracy : 91.40

Validation

Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	530	85
Actual Normal	105	780

F1 Score is : 0.891

Accuracy : 87.33

Testing

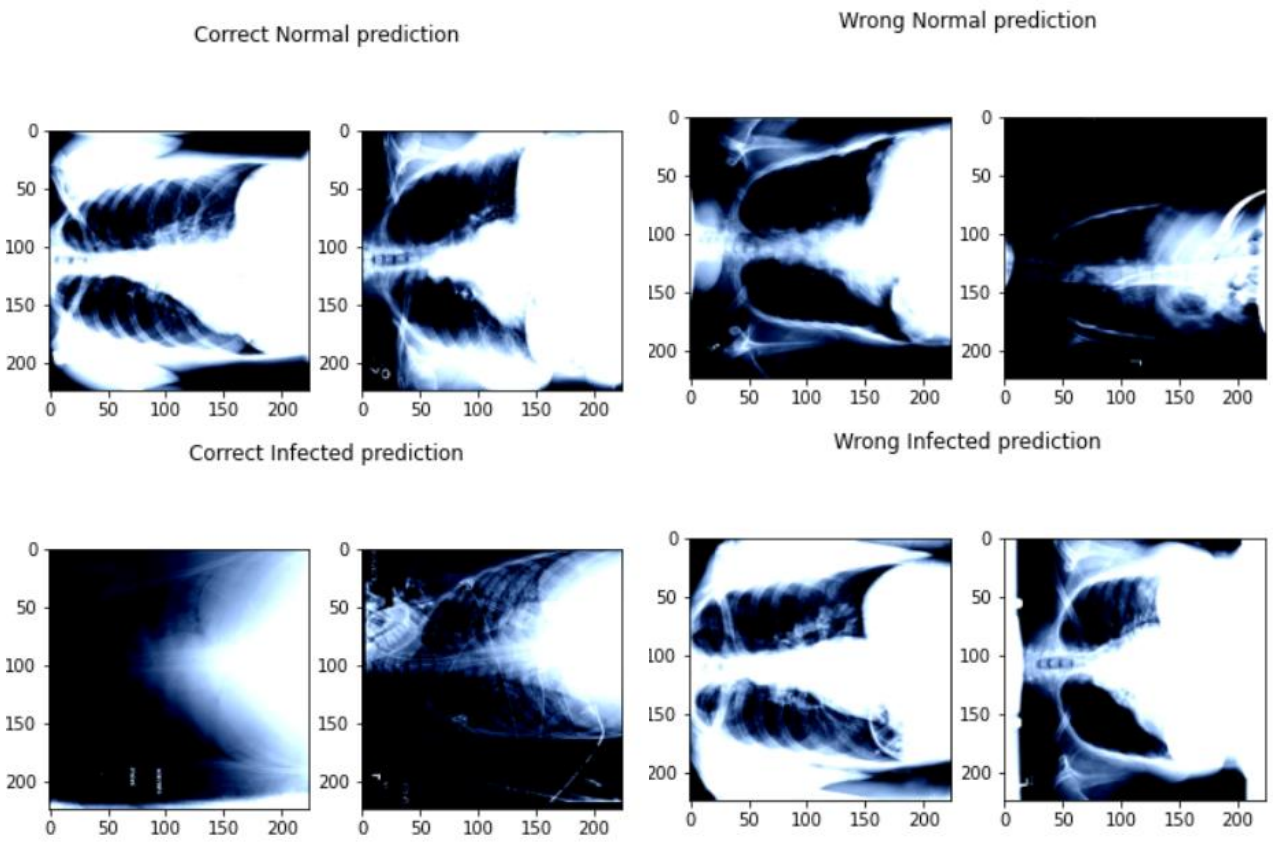
Confusion Matrix

	Predicted Infected	Predicted Normal
Actual Infected	582	33
Actual Normal	38	847

F1 Score is : 0.959

Accuracy : 95.26

Following are the two sample images from each class results.



COMPARISON AND ANALYSIS

Comparison Table

	Test Accuracy (%)	Test F-1 Score
TASK 1		
VGG16 FCLayer530, learning rate 0.001	90.06	0.921
VGG16 FCLayer530, learning rate 0.00001	93.60	0.947
VGG16 FCLayer 2000, learning rate 0.001	93.46	0.944
VGG16 FCLayer : 2000 , learning rate 0.00001	91.0	0.926
RESNET FCLayer530, learning rate 0.001	85.06	0.864
RESNET FCLayer530, learning rate 0.00001	86.86	0.885
RESNET FCLayer 2000, learning rate 0.00001	85.26	0.870
TASK 2		
VGG Net, learning rate 0.001	96.0	0.966
VGG Net 16, convolutional layers FREEZED, learning rate 0.001	96.6	0.971
VGG Net 16, convolutional layers freezed [0,2,5,10,24,28], learning rate 0.001	97.13	0.975
Res Net 18, No Freezing learning rate 0.001	96.66	0.971
Res Net 18, FC layers freeze, learning rate 0.001	96.8	0.973
Res Net 18,convolution 1 and 2 layers freeze, learning rate 0.001	95.26	0.976

It could be compared from the graphs over epochs that decreasing the learning rate, smooth the curve and the curve goes towards better accuracy and loss with smoothness, whereas, high learning rate tends to make abrupt changes, but it is also evident from the graphs that decreasing the learning rate makes the learning slow.

From Task 1, It could be illustrated that increasing the number of neurons also increase the accuracy and also the F1-score. Therefore, as the number of neurons is very less i.e., 530 and corresponding accuracy is 90%, whereas, increasing the number of neurons to 2000, the accuracy increased to 93.4. Similarly, in task 2 it is increased to 96%.

From Task 2, for some convolutional layers freeze, we observe that the accuracy is increased to 97.13 %. Whereas, whole unfreeze network gives 96.6% accuracy. Therefore, it could be said that the intermediate layers frozen, which could learn several parameters can give better results.

From the images of wrong identification, there are images which have contrast problem. The network is predicting them wrong; it is supposed that such networks are learning brightness at particular places rather

than texture or behavior.

Some of the X-Rays also have tubes or medical apparatus, it could be seen that such images are also predicted wrong.

Overall, the ResNet predict CoVID19 cases better than VGG, but with the fine tuning it is find that VGG16 is slightly better performing on the dataset, this behavior is mainly due to the higher number of convolution layers and the dataset properties.