Image Super-resolution based classification of COVID-19 patients using CNN-SVM.

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Abstract: ***The first case of the Coronavirus Disease (COVID-19) was registered in December 2019 in Wuhan, China. This extremely contagious disease spread worldwide in a very short time, thus resulting in a global pandemic. To curb the spread of COVID-19, it is important to detect the virus in an infected person at the earliest. In this paper, a downright study of Convolutional Neural Networks (CNN) and Support Vector Machines (SVM) will be presented for the classification of patients infected with the virus using X-ray and Computerized Tomography (CT) images. Using Transfer learning, features are extracted from the images using the fully connected CNN model and fed into the SVM for coronavirus classification.***

Keywords: ***Coronavirus, COVID-19, CNN, SVM, image-based diagnosis, Computerized Tomography, Transfer Learning.***

I. INTRODUCTION

The COVID-19 is an ongoing pandemic whose origins trace back to Wuhan. In December 2019, a virus similar to the SARS coronavirus emerged in Wuhan, China. This deadly and contagious virus was later renamed to SARS-CoV-2. Extensive research and studies conclude that this family of coronaviruses generally infect bats and pangolins in Asia. A little over 4 months from the first reported case of COVID-19, the World Health Organization (WHO), on 11th March 2020, announced the pandemic. Over 2020, this virus has infected 109 million people worldwide resulting in over 2.4 million deaths. The mortality rate of this virus is approximately 3.4%.

Virus	Year	Mortality Rate
SARS	2002	10%
MERS	2013	34%
SARS-CoV-2	2019	3.4%

Table 0 : Mortality Rates Comparison

The incubation period of COVID-19, which is the time between exposure to the virus and symptom onset, is on average 5-6 days, but can be as long as 14 days. In many instances, the infected people are asymptomatic. One of the vital reasons for the need to use intelligent systems for diagnosing COVID-19 is the high transmission rate of this disease among the people of a community. The time taken to generate the test result is comparatively greater than the time required to transmit this virus from one person to another. In such cases, X-ray images or CT scans can provide a faster and a convenient way to test the suspected individuals.

This study is intended for the same. It is targeted towards the employment of intelligent AI systems that can assist in the early detection of COVID-19 using chest X-ray and CT scan images. These systems will use Convolutional Neural Networks (CNN) for feature extraction and a Support Vector Machine (SVM) for disease classification.

II. LITERATURE REVIEW

<table>
<tr><th>Papers</th><th>DataSets</th><th>Images</th><th>Classes</th><th>Techniques & Performances(%)</th></tr>
<tr><td>[1]</td><td>Not mentioned</td><td>Not mentioned</td><td>2

COVID-19(+)
COVID-19(-)</td><td>
<table>
<tr><th>Model</th><th>ACC</th><th>SEN</th><th>SPE</th></tr>
<tr><td>MODE based CNN</td><td>98</td><td>98.2</td><td>92.2</td></tr>
</table></td></tr>
<tr><td>[2]</td><td>[21], [22], [23]</td><td>341 COVID-19(+)
2800 Normal
1493 Viral Pneumonia
2772 Bacterial Pneumonia</td><td>4

COVID-19(+)
Normal
Viral pneumonia
Bacterial Pneumonia</td><td>
<table>
<tr><th>Model</th><th>ACC</th><th>REC</th><th>SPE</th><th>F1</th></tr>
<tr><td>ResNet50</td><td>96.1</td><td>91.8</td><td>96.6</td><td>83.5</td></tr>
<tr><td>ResNet101</td><td>96.1</td><td>78.3</td><td>98.2</td><td>81.2</td></tr>
<tr><td>ResNet152</td><td>93.9</td><td>65.4</td><td>97.3</td><td>69.8</td></tr>
<tr><td>InceptionV3</td><td>95.4</td><td>90.6</td><td>96.0</td><td>81.1</td></tr>
<tr><td>Inception-ResNet</td><td>94.2</td><td>83.5</td><td>95.4</td><td>74.8</td></tr>
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<tr><td>[3]</td><td>[21]</td><td>341 COVID-19(+)
310 Normal
310 Pneumonia</td><td>3

COVID-19(+)
Normal
Pneumonia classes</td><td>
<table>
<tr><th>Model</th><th>ACC</th><th>SEN</th><th>SPE</th></tr>
<tr><td>AOTCNeT-Softmax</td><td>99.24</td><td>99.24</td><td>99.62</td></tr>
<tr><td>SVM</td><td>98.60</td><td>98.60</td><td>99.30</td></tr>
<tr><td>RF</td><td>99.46</td><td>99.46</td><td>99.73</td></tr>
<tr><td>KNN</td><td>99.46</td><td>99.46</td><td>99.73</td></tr>
<tr><td>MobileNet-KNN</td><td>99.46</td><td>99.46</td><td>99.73</td></tr>
<tr><td>ShuffleNet-KNN</td><td>99.35</td><td>99.35</td><td>99.68</td></tr>
</table></td></tr>
<tr><td>[4]</td><td>[21]</td><td>150 COVID19(+)
150 Normal</td><td>2

COVID-19(+)
COVID-19(-)</td><td>
<table>
<tr><th>Model</th><th>ACC</th><th>REC</th><th>SPE</th><th>F1</th></tr>
<tr><td>CNN-Adam</td><td>94.6</td><td>93.5</td><td>94.5</td><td>90.7</td></tr>
<tr><td>CNN-RMSprop</td><td>88.9</td><td>85.9</td><td>88.9</td><td>86.6</td></tr>
<tr><td>CNN-SGD</td><td>88.4</td><td>88.7</td><td>88.5</td><td>83.0</td></tr>
</table></td></tr>
<tr><td>[5]</td><td>[21], [22]</td><td>284 COVID-19(+)
310 Normal
330 Pneumonia Bacterial
327 Pneumonia Viral</td><td>4

COVID-19(+)
Normal
Viral pneumonia
Bacterial Pneumonia</td><td>
<table>
<tr><th>Model</th><th>ACC</th><th>REC</th><th>SPE</th><th>F1</th></tr>
<tr><td>CORO-Net</td><td>90.21</td><td>90</td><td>95</td><td>91</td></tr>
</table></td></tr>
<tr><td>[6]</td><td>[27]</td><td>219 COVID-19(+)
1341 Normal
1345 Pneumonia</td><td>3

COVID-19(+)
Normal
Pneumonia classes</td><td>
<table>
<tr><th>Model</th><th>ACC</th><th>SEN</th><th>SPE</th><th>F1</th></tr>
<tr><td>mAlexNet</td><td>98.14</td><td>98.26</td><td>99.06</td><td>98.2</td></tr>
<tr><td>mAlexNet + BiLSTM</td><td>98.7</td><td>98.76</td><td>99.33</td><td>98.76</td></tr>
</table></td></tr>
<tr><td>[9]</td><td>[25]</td><td>349 COVID-19(+)
360 Normal</td><td>2

COVID-19(+)
COVID-19(-)</td><td>
<table>
<tr><th>Model</th><th>ACC</th></tr>
<tr><td>GoogleNet CNN</td><td>82.14</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>[10]</td><td>[23], [25]</td><td>136 COVID-19(+)
310 Normal
162 Pneumonia</td><td>3

COVID-19(+)
Normal
Pneumonia classes</td><td><table><tr><th>Model</th><th>ACC</th><th>REC</th><th>SPE</th><th>F1</th></tr><tr><td>Improved ResNet</td><td>96.30</td><td>96</td><td>98</td><td>96</td></tr><tr><td>ResNet 50</td><td>92.59</td><td>92.5</td><td>94</td><td>92</td></tr><tr><td>AlexNet</td><td>88.89</td><td>88.2</td><td>95</td><td>86.5</td></tr><tr><td>GoogleNet</td><td>90.74</td><td>92.5</td><td>96.1</td><td>90.12</td></tr><tr><td>VGG-16</td><td>91.66</td><td>96.49</td><td>92.2</td><td>91.5</td></tr></table></td></tr>
<tr><td>[11],
[12]</td><td>[21], [27]</td><td>125 COVID-19(+)
500 Normal
500 Pneumonia</td><td>3

COVID-19(+)
Normal
Pneumonia classes</td><td><table><tr><th>Model</th><th>ACC</th><th>F1</th></tr><tr><td>COVID-Net</td><td>92.4</td><td>90</td></tr><tr><td>Bayes-SqueezeNet</td><td>98.3</td><td>98.3</td></tr><tr><td>VGG-19</td><td>93.48</td><td>-</td></tr><tr><td>MobileNet-V2</td><td>94.72</td><td>-</td></tr><tr><td>ResNet 50+SVM</td><td>-</td><td>95.52</td></tr><tr><td>DarkCOVIDNet</td><td>87.02</td><td>87.37</td></tr><tr><td>CORO NET</td><td>95</td><td>95.6</td></tr><tr><td>VGG-16</td><td>99.57</td><td>99.36</td></tr></table></td></tr>
<tr><td>[14]</td><td>[28]</td><td>430 COVID-19(+)
550 Normal</td><td>2

COVID-19(+)
COVID-19(-)</td><td><table><tr><th>Model</th><th>ACC</th><th>REC</th><th>F1</th></tr><tr><td>MLP</td><td>0.9400</td><td>0.8715</td><td>0.9268</td></tr><tr><td>CNN</td><td>0.9760</td><td>0.9724</td><td>0.9724</td></tr><tr><td>SVM</td><td>0.9920</td><td>1.000</td><td>0.990</td></tr><tr><td>NB</td><td>0.9400</td><td>0.9541</td><td>0.9327</td></tr><tr><td>AdaBoost</td><td>0.9600</td><td>0.9633</td><td>0.9545</td></tr><tr><td>GBDT</td><td>0.9520</td><td>0.9816</td><td>0.9469</td></tr></table></td></tr>
<tr><td>[15]</td><td>[21], [29]</td><td>912 images</td><td>2

COVID-19 (+ve)
COVID-19 (-ve)</td><td><table><tr><th>Model</th><th>ACC</th><th>SEN</th><th>SPE</th></tr><tr><td>CNN-Softmax</td><td>95.2</td><td>93.3</td><td>100</td></tr><tr><td>CNN-SVM</td><td>90.5</td><td>86.7</td><td>100</td></tr><tr><td>CNN-RF</td><td>81</td><td>76.5</td><td>100</td></tr></table></td></tr>
<tr><td>[16]</td><td>No access link (only mentioned GitHub)</td><td>No access link (only mentioned GitHub)</td><td>2

COVID-19 (+ve)
COVID-19 (-ve)</td><td><table><tr><th>Model</th><th>ACC</th></tr><tr><td>GLCN -> SVM</td><td>57.1</td></tr></table></td></tr>
<tr><td>[17]</td><td>Manual Data Collection through Google Forms.
(text format)</td><td>Manual Data Collection through Google Forms.
(text format)</td><td>2

COVID-19 (+ve)
COVID-19 (-ve)</td><td><table><tr><th>Model</th><th>Mean (%)</th><th>STD(%)</th></tr><tr><td>LR</td><td>96.667</td><td>10</td></tr><tr><td>SVM</td><td>97.78</td><td>6.67</td></tr><tr><td>DT</td><td>93.33</td><td>13.333</td></tr><tr><td>KNN</td><td>78.33</td><td>23.629</td></tr></table></td></tr>
</table>

<table>
<tr><td>[18]</td><td>[27]</td><td>1200 COVID-19 (+)
1345 Pneumonia
1341 Normal</td><td>3

COVID-19
Normal
Pneumonia classes</td><td>
<table>
<tr><th>Model</th><th>Class</th><th>ACC</th><th>REC</th><th>F1</th></tr>
<tr><td>CNN</td><td>COVID-19</td><td></td><td>99.79</td><td>99.69</td></tr>
<tr><td></td><td>Pneumonia</td><td>96.90</td><td>99.44</td><td>95.53</td></tr>
<tr><td></td><td>Normal</td><td></td><td>90.94</td><td>94.89</td></tr>
<tr><td>CNN-SVM</td><td>COVID-19</td><td></td><td>99.75</td><td>99.85</td></tr>
<tr><td></td><td>Pneumonia</td><td>99.53</td><td>99.48</td><td>99.40</td></tr>
<tr><td></td><td>Normal</td><td></td><td>99.41</td><td>99.39</td></tr>
</table>
</td></tr>
<tr><td>[19]</td><td>[21], [26]</td><td>217 COVID-19
108 Other Diseases
112 Healthy</td><td>3

COVID-19
Healthy
Other Diseases</td><td>
<table>
<tr><th>Model</th><th>ACC</th><th>F1</th><th>MCC</th></tr>
<tr><td>CNN$_1$</td><td>96.67</td><td>96.63</td><td>93.48</td></tr>
<tr><td>CNN$_2$</td><td>96.73</td><td>96.67</td><td>93.74</td></tr>
<tr><td>SVM$_{Lin}$</td><td>80.79</td><td>80.21</td><td>61.98</td></tr>
<tr><td>SVM$_{Pol}$</td><td>77.90</td><td>77.24</td><td>56.30</td></tr>
<tr><td>SVM$_{RBF}$</td><td>83.45</td><td>83.86</td><td>67.39</td></tr>
</table>
</td></tr>
<tr><td>[20]</td><td>[21], [25]</td><td>127 COVID-19 (+ve)
127 Pneumonia (+ve)
127 healthy</td><td>3

COVID-19
Normal
Pneumonia classes</td><td>
<table>
<tr><th>Model</th><th>SEN</th><th>FPR</th><th>F1</th></tr>
<tr><td>AlexNet</td><td>94.86</td><td>2.56</td><td>94.85</td></tr>
<tr><td>GoogleNet</td><td>91.73</td><td>4.13</td><td>91.74</td></tr>
<tr><td>InceptionV3</td><td>90.26</td><td>4.86</td><td>90.28</td></tr>
<tr><td>MobileNetV2</td><td>94.46</td><td>2.76</td><td>94.46</td></tr>
<tr><td>ResNet18</td><td>94.26</td><td>2.86</td><td>94.25</td></tr>
<tr><td>ShuffleNet</td><td>65.26</td><td>17.36</td><td>58.79</td></tr>
<tr><td>VGG16</td><td>94.20</td><td>2.90</td><td>94.20</td></tr>
</table>
</td></tr>
</table>

Table 1 : SUMMARY OF ML and DL BASED COVID-19 DIAGNOSIS IN CT IMAGES

III. METHODOLOGY

The methodology implemented can be divided into these basic steps:

A. Image Preprocessing :

This involves importing images and converting all the images to a standard 224*244 grayscale image. Since VGG16 is a pretrained model its input configuration cannot be changed. So we can copy the first Chanel values to the other two channels and create a 3 channel image out of your gray scale image.

B. Dataset Split :

The dataset will be split into 8:2 ratio i.e. into training and validation sets respectively. Although the Base paper[11] used a 7:3 split according to the reference paper[7] the best performing split according to the given dataset was 8:2.

C. Feature Extraction :

We move on to use a pre-trained model in order to extract the features most beneficial in distinguishing between pneumonia, covid infected and non infected persons. For this purpose, we will be using the transfer learning technique that is ImageNet and VGG-CNN model to extract features in the form of weights and feed these as inputs as an input feature map to a fully connected deep neural network classifier.

We will be using the VGG16 Convolution neural network coupled with Relu activation function for classification purposes. A brief description of working of our CNN model os as follows :

The 224*224*3, 3 channel grayscale images are passed through a stack of convolutional (conv.) layers, where the filters were used with the smallest receptive field of 3×3 to capture the notion of left or right, up or down and center. In one of the convolutional layer configurations, we use 1×1 convolution filters, which is supposed to act as a linear transformation of the input channels.

Spatial pooling is carried out by five max-pooling layers, which follow after every few convolutional layers. Max-pooling is performed over a 2×2 pixel window. Three Fully-Connected (FC) layers follow after a stack of convolutional layers. The first two FC layers have 4096 channels each, whereas the third layer contains 1000 channels.

D. Classifier :

We will be using SVM coupled with the Radial basis function (rbf) kernel as our classifier. Below is the flow chart of the aforementioned methodology.

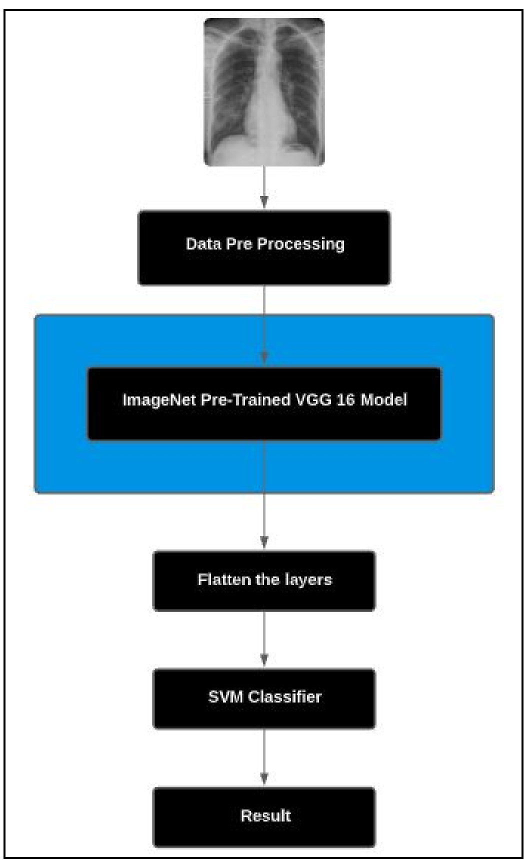

Figure 1 : Methodology

The final result will be a classification between 3 classes (Normal, COVID-19(+) and Pneumonia).

IV. DATASET

A. Dataset I

The primary dataset is obtained from a GitHub repository. It contains images of three classes, namely COVID-19, Pneumonia and Healthy. The number of images from each class have been recorded below.

Class	No. of Images
Healthy	500
Pneumonia	500
COVID-19(+)	125

Table 2 : Dataset 1 summary

B. Dataset II

The second dataset is the Mendeley Dataset. It contains images of two classes, namely COVID and non-COVID. There are 878 and 912 X-ray images respectively.

Class	No. of Images
Non - COVID-19	912
COVID-19	878

Table 3 : Dataset 2 summary

V. SOFTWARE AND HARDWARE REQUIREMENTS

Software	Hardware
Numpy	Intel i5

Pandas Pytorch sklearn Keras Tensorflow	8 GB RAM

Table 4 : Requirements

VI. REFERENCES

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