

Real-time Face Mask Detection using MTCNN, PCA, and SVM

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1 Introduction

Quite some effort has been put into public-space computer vision applications to help combat the ongoing COVID-19 pandemic. One such application, **Real-time face mask detection**, involves first the detection of faces in a given frame of a video feed, and then the classification of each face to detect if the person is wearing a mask or not. If implemented nationwide, such Computer Vision solutions can have a profound impact on the spread of the virus that has created a pandemic.

Support Vector Machines (SVMs) have been proven to be great at a variety of classification and regression problems. We aim to create an application using a machine learning model that utilizes **Principal Component Analysis (PCA)** to reduce the dimensionality of image data, and then classify the image of a face as **with_mask**, **without_mask**, or as **mask_wearred_incorrect** (n.b: this name was a grammatical error in the labels. We will use it as-is to stay in agreement with the dataset used) with the help of an SVM.

We aim to create a real-time classification application that detects faces from a webcam using a pre-trained Multi-Task Cascaded Convolutional Neural Network (**facenet-pytorch MTCNN**).

2 Application Structure

Our real-time face mask detection application consists of 4 steps:

1. Sampling frames from the live feed from a camera
2. Finding all the faces through their bounding box coordinates given a frame, through MTCNN
3. Passing each individual face to the PCA-SVM pipeline and classifying them as either **with_mask**, **without_mask**, or as **mask_wearred_incorrect**

4. Displaying the result as the frame with a colored frame overlay which is green (**with_mask**), orange (**mask_wearred_incorrect**), or red (**without_mask**)

3 Dataset Selection for the Classifier

For training the model required for classifying face images, we chose the **face-mask-detection** dataset from Kaggle. The dataset consists of two directories:

- **annotations/**, which contains 853 XML files with metadata including:
 1. The image filename
 2. Labels for each face in each image (**with_mask**, **without_mask**, or **mask_wearred_incorrect**)
 3. Face bounding boxes for the corresponding training image.
 4. The name of the XML file is formatted as: [name_of_image].xml
- **images/**, which contains 853 PNG image files

The data was processed using Python into:

1. A numpy array, **data**, where each element is a flattened float32 array of length (224x224x3) generated from 224x224 scaled RGB images of extracted faces based on the annotation XML file data.
2. A numpy array, **labels**, that contains the string label for each corresponding sample in the **data** array.
3. A numpy array, **label_data**, that contains an integer label (0, 1, 2) for each corresponding sample in the **data** array.

The **data** and **labels** array construction process was borrowed from [4].

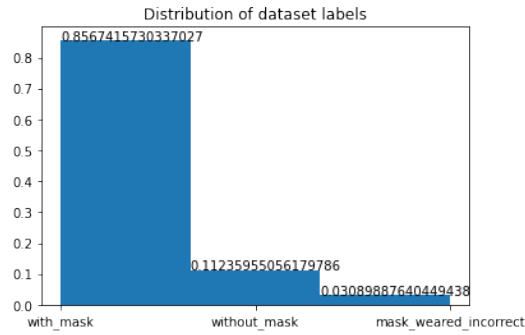


Figure 1: Dataset Label Histogram

4 Classifier Model - Training and Analysis

We used the PCA algorithm offered by the **scikit-learn** library to extract the top 70 principal components and thus reduce the number of features the SVM classifier will need to deal with.

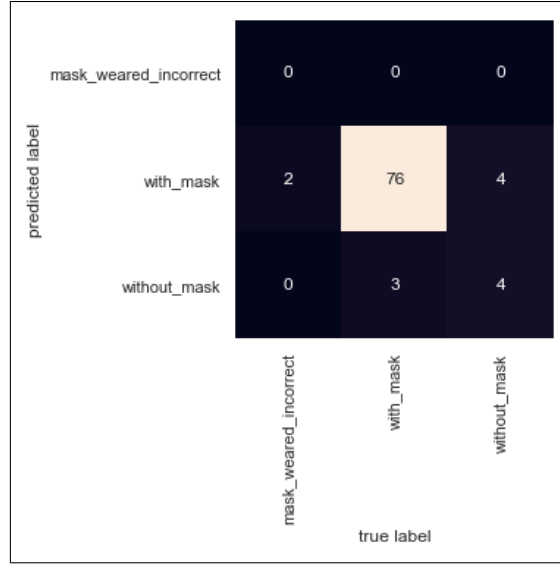


Figure 2: Confusion Matrix for the PCA-SVM classifier

The output of the PCA algorithm was pipelined into the SVM classifier provided by the **scikit-learn** library. The SVM classifier uses a radial basis function (**rbf**) kernel, which is a proven method [3] for clustering high-dimensional data.

	precision	recall	f1-score	support
mask_wearred_incorrect	0.00	0.00	0.00	2
with_mask	0.93	0.96	0.94	79
without_mask	0.57	0.5	0.53	8
accuracy			0.90	89
macro avg	0.5	0.49	0.49	89
weighted avg	0.87	0.90	0.89	89

Table 1: Classification Report for the PCA-SVM classifier

We achieved an accuracy of 89.88% with hyperparameters $C=20$ and $\gamma=0.005$ for the SVM, which were found using the **GridSearchCV** cross validation helper from the **scikitlearn** library. From the confusion matrix (Figure 1), and the classification report (Table 1), we can conclude that our model can easily identify the **with_mask** class, and can make fair sense of whether or not

a person has worn a mask. Due to lack of enough training samples, it fails to detect improperly worn masks.

5 Face Detection using MTCNN

MTCNN provides a robust, pre-trained neural network model ideal for detecting faces on a live camera feed. We used it on our application to provide a cropped and scaled image of only the detected face to the PCA-SVM pipeline on the fly. The model output is then used to color the bounding box of the detected face.

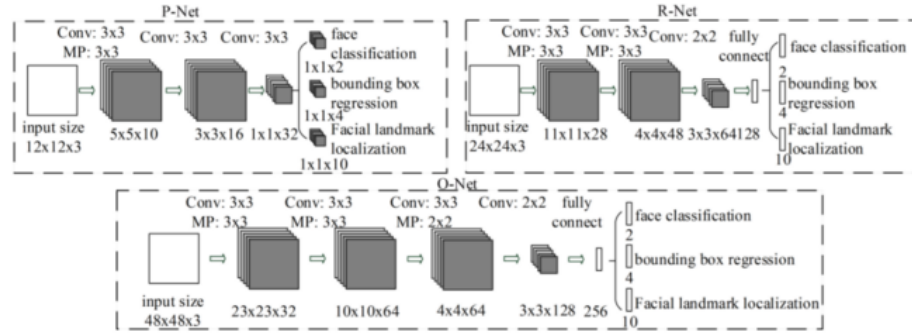


Figure 3: A quick overview of the basic structure of the MTCNN Model.[2]

MTCNN features 3-stages, each having a deep neural network with several layers:

1. The P-net - determines the probability of a face in a given kernel
2. The R-net - refines the coordinates of the boxes bounded by the P-Net
3. The O-net - takes R-net bounds and then determines facial landmarks

6 Conclusion

Apart from failing to usually detect the **mask_worned_incorrect** class, as can be observed in Figure 4, our model is satisfactorily able to perform the essential classification between **with_mask** and **without_mask**.

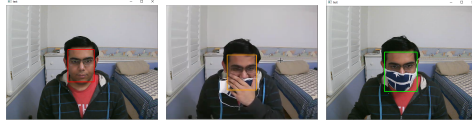


Figure 4: App output: red - no mask, orange - improper, green - with mask

References

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