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COVID-19 Segmentation and Classification from CT Scan Images

Sridevi Ramachandra Rathod[1] and Harmeet Kaur Khanuja[2]

[1,2] Department of Computer Engineering, MMCOE, Pune, India
rathodsridevi@gmail.com

Abstract. The pandemic corona virus disease 2019 (COVID-19) has rapidly spread to most countries worldwide. Since the year 2019, the world has been facing a global health crisis. Therefore, an automated detection of lung infections is very necessary to tackle COVID-19. For this reason, we develop a framework to automatically segment COVID-19 CT images using K-means Clustering and use them to train proposed Convolutional Neural Network to classify COVID-19 from the normal CT images. Rapid growth in deep learning has led to a series of breakthroughs for image analysis, thereby reducing time of radiologists in the diagnosis of COVID-19. Our framework is evaluated upon 349 positive and 397 negative CT scans to detect COVID-19 & help in taking appropriate diagnostic decisions. To evaluate the performance of our proposed approach, we compared our results with pre-trained models such as VGG19, Inception V3 and ResNet50.

Keywords: COVID-19, CT image, Segmentation, K-means, Pneumonia, Deep learning, Convolutional neural network.

1 Introduction

The rapidly spreading CoronaVirus Disease-2019 (COVID-19) has become a worldwide pandemic since the year 2019, originated in Wuhan in China. The coronavirus is a kind of virus that leads to illness such as common cold, Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS). The coronavirus disease affects different people in different ways. Some people get cured without hospitalization and in some cases it leads to death due to critical complications. Along with the most usual symptoms of COVID-19 such as cough, shortness of breath and fever, the COVID-19 infected patients will also suffer from Pneumonia.

The characteristics of Pneumonia found in COVID-19 patients may be like characteristics of Pneumonia obtained by other viruses or bacteria. Therefore, it is difficult to find the source of the disease without carrying out COVID-19 test or any kind of repiratory infection tests. According to some researchers [7], it is said that patients with COVID-19 Pneumonia have their both lungs affected by Pneumonia but not just one lung and the Pneumonia has pattern of ground glass opacity via CT scan. In clinic practice, errors in segmentation can cause critical wrong results. Therefore, in medical image analysis, segmentation of lesions or infection portions require greater level of efficiency compared to natural or common images.

As per records of world health organization (WHO) [8], worldwide COVID-19, as of 19 July 2021, confirmed cases are 192,284,207, confirmed deaths are 4,136,518. The CT (Computed Tomography) imaging technology plays an important role in the identification of characteristics in the lung occurred by COVID-19. To diagnose the disease COVID-19 accurately and to assist in longitudinal study of the disease, segmentation of lesions known as infected portions from CT scans is very necessary. To find quantifiable value of disease progression, the imaging techniques such as CT scan or Chest X-ray are being used as a part in the diagnosis of COVID-19. Doctors can easily visualize the changes that occur due to COVID-19 Pneumonia in our lungs with the help of the imaging techniques. The testing of this coronavirus disease manually, needs a large number of testing kits which are very expensive and blood tests, where a blood test can be inefficient and needs some hours of time to arrive at the testing result. Therefore, to overcome these situations, in order to provide better and efficient treatment, deep learning techniques are being used in the diagnostic process of COVID-19.

In this paper, we aim to build an automatic segmentation model of COVID-19 pneumonia lesions from CT images using K-means clustering and its classification using Convolutional Neural Network to achieve better performance.

The remainder of this paper is organized as follows. Section II briefly introduces existing works to deal with COVID-19. In Section III, the proposed framework to automatically segment & classify COVID-19 is introduced. Results and discussions are shown in Section IV. Conclusion is shown in the final section.

2 Literature Survey

Existing works performed on segmentation and classification of COVID-19 Pneumonia from the given X-ray or CT images to help in diagnosing of COVID-19 are presented below.

The study [1], presents a new coronavirus disease (2019-nCoV) which belongs to the category of betacoronavirus. The novel coronavirus is found in patients of Wuhan's hospitals and is recognized with the help of techniques such as molecular and un-biased DNA sequencing. The drawback of this study is that it does not satisfy Koch's postulates. In [2] authors report epidemic transmission of the virus and its history, by using the approach of epidemiology in combination

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with molecular process to focus on genetic variation in pathogens. This study helps in preventing future epidemics like SARS-CoV and 2019-CoV.

Authors [3], determined a parameter from CT image known as percentage of lung opacification (QCT-PLO) by using a deep learning tool. The quantitative parameter QCT-PLO is greatly increased between baseline CT and 1st follow-up CT. Limitation of this study is that it needs supervision of radiologists as there is no clarification of pulmonary opacities. Authors [4], presented convolutional neural network approach made up of multiple layers. This multi-layered approach is used to analyse medical images, where as the model's first layer is used to detect motifs by applying filters. Limitation of this approach is that there is no fixed number of layers and filters.

In the work [5], full convolution neural network is trained with the proposed spatially adaptive reweighting technique, where weights generated depend on local texture of the image. The approach is tested upon skin images dataset in order to segment skin lesions. One of the merits of this model is that it uses lesser number of clean and larger number of noisy data. The study [6], uses bidirectional chain coding technique with support vector machine as classifier. Over-segmentation is reduced by implementing point pairs selection technique. Experimenting on juxtapleural nodules, the proposed model achieves good overlap ratio. The approach can deal with low quality images but there is no re-inclusion of nodules attached to the lung wall in consolidation areas. In our previous study [9], we presented a brief survey of works carried out on segmentation and classification of COVID-19. The study [9], presents comparative study of various techniques used in the process of COVID-19 diagnosis along with their merits and demerits. And it has shown that convolutional neural networks have obtained higher accuracy comparatively. Authors [10], used pre-trained models of CNN for X-ray images of COVID-19.They have used multi-level feature representation and decreased error rate but their approach was computationally expensive and slow in learning.

Existing studies reveal that there are certain limitations concerning incomplete, inaccurate images, labelled data and require more number of iterations. Based on the above, it has been found that not much work has been carried out for training the network using segmented images. Therefore, we aim at developing an automatic model for segmentation & classification of COVID-19 using deep learning framework to achieve higher performance.

3 Proposed Methodology

In this work, we aim at developing an automatic segmentation and classification model of COVID-19 Pneumonia lesions from CT scan images using K-means clustering and proposed Convolutional Neural Network to achieve better performance.

The system architecture diagram of our model is as shown in Fig. 1. The model consists of four modules such as image pre-processing, segmentation using K-means, feature extraction and classification using CNN. Data, here are set of CT scan images of COVID-19 patients. The pre-processing phase involves conversion of color image to gray scale using OpenCV function, resizing the image and filtering the image by applying Gaussian filter of size (7,7). With the benefit of Fourier transform of Gaussian filter, near-by pixels have a bigger influence on the smoothed rather than more distant ones. The segmentation phase produces required four clusters using K-means clustering. Then feature extraction is done from segmented images using Convolution layer of CNN and finally classification as COVID or normal is done using CNN based classifier such as Sigmoid. The proposed system, respective algorithms and mathematical model are introduced below.

3.1 Architecture

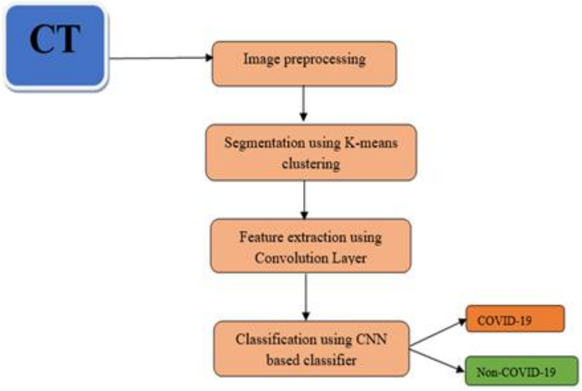

Fig. 1. Proposed System Architecture.

3.2 Algorithms

K-means clustering

The segmentation phase is performed using K-means clustering algorithm. The input for segmentation phase is pre-processed CT scan image of COVID-19. Segmentation is the classification of an image into many parts or regions. Here segmentation of pneumonia lesions from CT scan images of COVID-19 is done. K-means clustering is used to segment the image into different clusters. Clustering the intensity values of the image into different regions or clusters.

K-value is chosen based on desired number of clusters. Then randomly choosing the centers of k clusters and calculating mean of the cluster. Based on Euclidean distance between each pixel and each cluster, every pixel is assigned to a cluster. Re-estimating the center and repeating the process until the center doesn't move. Finally, we get the clusters containing similar data points and the output of the segmentation phase is the image used to train the proposed Convolutional Neural Network for classification task.

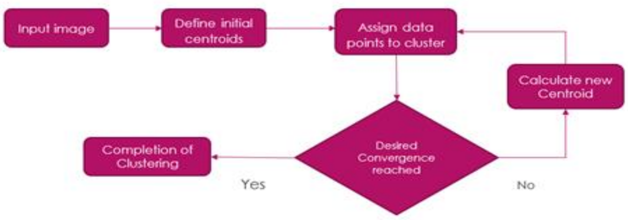

Fig. 2. Flow of K-means Algorithm.

Suppose we have a set of data points $\{x_1, x_2, \dots, x_n\}$ and we wish to have k clusters given by $\{c_1, c_2, \dots. c_k\}$, then the aim of K-means is to minimize within cluster sum of squares (WCSS) [11]. Each cluster is assigned a mean or centroid value. If x_i is each data point in the set and μ_i is mean of cluster i then distance between x_i and μ_i is given by the equation,

$$V = \sum_i (\mu_i - x_i)^2$$

The goal is to reduce the squared error function or objective function J given by,

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} ||x_i^{(j)} - \mu_j||^2$$

where, k is the no. of clusters and n is the no. of data points.

Proposed Convolutional Neural Network

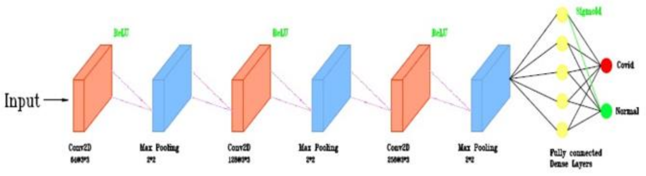

Fig. 3. Proposed Convolutional Neural Network.

After the segmentation phase, features are extracted from the segmented image using convolution layer. Based on the features learned, classification is done using CNN based classifier.

As shown in Fig. 3., the building blocks of CNN architecture are convolutional layers, pooling layers and fully connected layers. Let the input be a 2D CT image, then 2D convolutional layer is applied to extract the local features from the input image, using a fixed size filter called kernel. The pooling layers perform sub-sampling to reduce the size of feature maps. The features from the convolutional layers are propagated till the last fully connected layer, which uses sigmoid activation function for prediction as 0 or 1.

The output of the classification phase is in two categories. One class is consisting images of COVID-19 detection and another class consisting of images of non-COVID-19 detection.

The proposed CNN is made up of 3 convolution layers using a filter of size 3*3 and 3 max pooling layers using a filter of size 2*2. ReLu activation is used along with convolution layers to speed-up training time. Besides the convolution and pooling layers, two fully connected dense layers are used. Finally Sigmoid activation function is used for classification.

4 Results and Discussions

For our model, we use an open-sourced data set consisting of 349 CT scan images of confirmed COVID-19 from 216 patients and 397 non-COVID-19 CTs. The utility of this dataset is confirmed by a senior radiologist who has been treating COVID-19 patients. The data set is available at https://www.kaggle.com/luisblanche/covidct. Experimental evaluation is done to compare the results for evaluating the performance. For experimental result evaluation, we use the confusion matrix with the following notations:

TP: Correctly prediction of the positive samples
FP: Incorrectly prediction of the positive samples
TN: Correctly prediction of the negative samples
FN: Incorrectly prediction of the negative samples

On the basis of these parameters, we can evaluate the accuracy as follows:

Accuracy = (TP+TN) / (TP+TN+FP+FN)
Sensitivity = TP / (TP+FN)
Specificity = TN / (TN+FP)
Precision = TP / (TP+FP)
F1-score = 2*((precision*recall) / (precision+recall))

The dataset consists a total of 746 CT scan images. 80% of the data is used for training and remaining 20% of the data is used for testing. Figure 5, shows sample COVID positive and normal CT scan from the dataset.

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 48, 48, 64)	640
max_pooling2d (MaxPooling2D)	(None, 24, 24, 64)	0
conv2d_1 (Conv2D)	(None, 22, 22, 128)	73856
max_pooling2d_1 (MaxPooling2	(None, 11, 11, 128)	0
conv2d_2 (Conv2D)	(None, 9, 9, 256)	295168
max_pooling2d_2 (MaxPooling2	(None, 4, 4, 256)	0
flatten (Flatten)	(None, 4096)	0
dense (Dense)	(None, 64)	262208
dense_1 (Dense)	(None, 1)	65
activation (Activation)	(None, 1)	0

Total params: 631,937
Trainable params: 631,937
Non-trainable params: 0

Fig. 4. Model Summary of the proposed CNN.

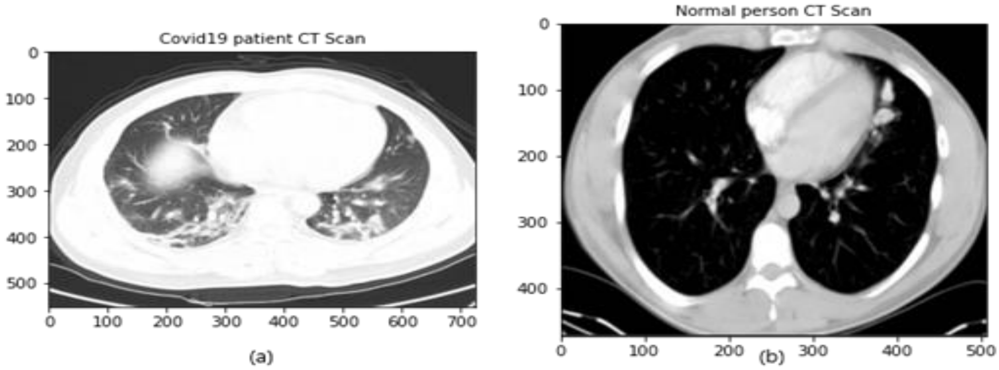

Fig. 5. Sample Original images in dataset. (a) COVID CT (b) Normal CT.

Following, in figure 6, outputs of preprocessing phase are shown for a sample image. The grayscale image is obtained by applying OpenCV gray scale conversion function and filtered image is obtained by applying OpenCV Gaussian function.

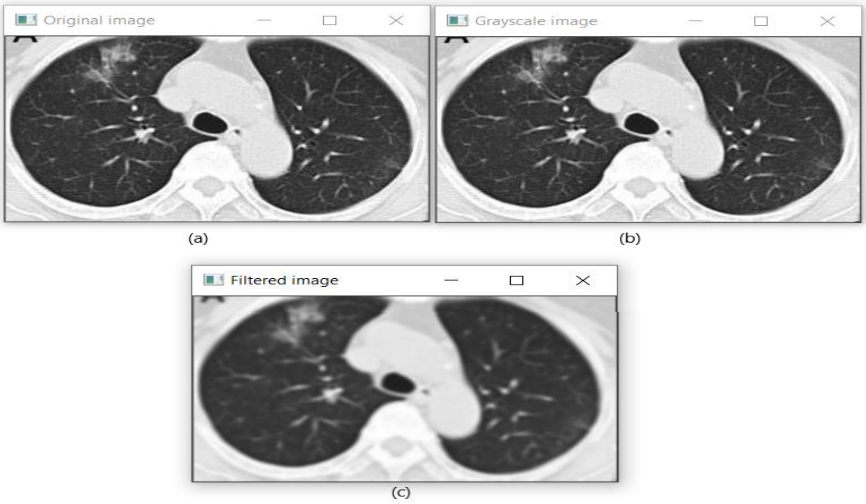

Fig. 6. Outputs of Preprocessing phase. (a) Original image (b) Gray image (c) Filtered image.

After applying K-means algorithm for the COVID positive CT scan with value of k=4, following results are obtained as shown in figure 7. The cluster 3 or extracted image 3 contains the COVID-19 Pneumonia Lesions.

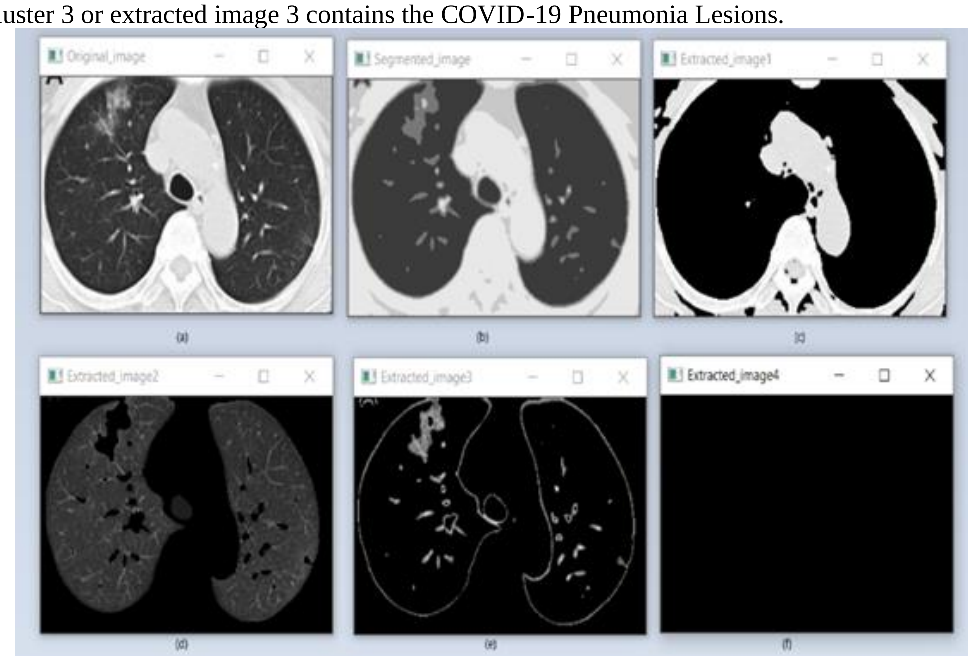

Fig. 7. K-means Output images. (a) Original (b) Segmented (c) Cluster 1 (d) Cluster 2 (e) Cluster 3 (f) Cluster 4.

Following, in figure 8, are some original COVID CT scans along with their segmented images using K-means clustering with k=4.The original image is segmented in four clusters with black, white, dark gray and light gray colors.

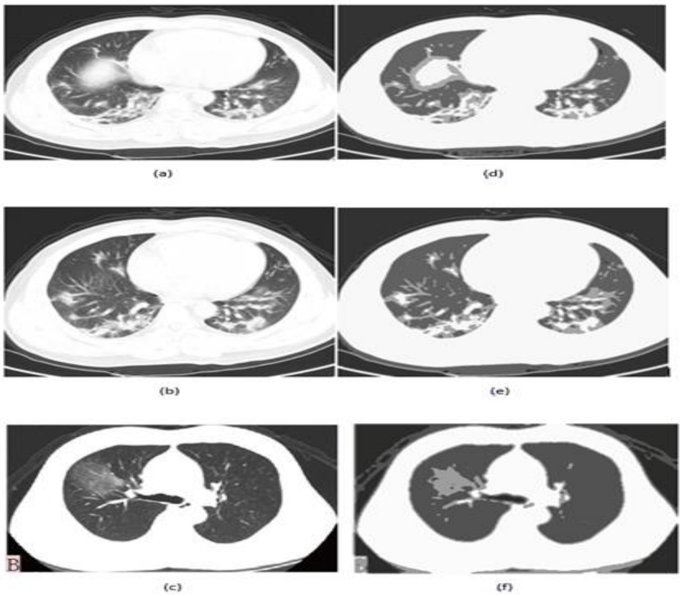

Fig. 8. Sample Original and Segmented results. (a)-(c) Original COVID images & (d)-(f) Segmented images.

The proposed model is trained once with un-segmented (before applying K-means) images (CNN) and once with segmented (after applying K-means) images (CNN_Seg). The accuracy of the model is improved with segmented images, ie. CNN_Seg. Performance of the proposed model is compared with pre-trained networks such as VGG19, InceptionV3 and ResNet50. Table 1., shows the results for training and validation accuracies, precisions, recalls and losses of various models. Proposed CNN_Seg has achieved accuracy of 93.96% which is higher than proposed CNN and other models. As shown in Table 2, proposed CNN_Seg has achieved F1-score of 75.81% which is greater than proposed CNN & other models.

Table 1. Comparative results based on training and validation.

Model v/s Metrics	Accuracy (%)	Precision (%)	Recall (%)	Loss (%)	Val_ Accuracy (%)	Val_ Precision (%)	Val_ Recall (%)	Val_ Loss (%)
VGG_19	76.47	76.47	76.47	52.09	68.00	68.67	68.67	57.42
ResNet50	59.04	59.04	59.04	77.21	65.33	65.33	65.33	64.48
Inception V3	68.74	68.74	68.74	98.65	68.00	68.00	68.00	89.63
Proposed CNN	89.56	89.87	91.48	23.22	68.00	66.32	79.75	67.44
Proposed CNN_Seg	93.96	96.16	92.32	18.34	75.33	75.32	76.32	57.35

Table 2. Comparative results based on evaluation metrics.

Model v/s Metrics	Image_size (pixels)	Sensitivity (%)	Specificity (%)	F1-score (%)	Overall accuracy (%)
VGG_19	224*224	68.85	68.53	64.12	68.00
ResNet50	224*224	71.42	62.96	53.57	65.00
InceptionV3	224*224	64.10	72.22	67.56	68.00
Proposed CNN	50*50	70.90	66.31	72.41	68.00
Proposed CNN_Seg	50*50	75.34	75.32	75.81	75.33

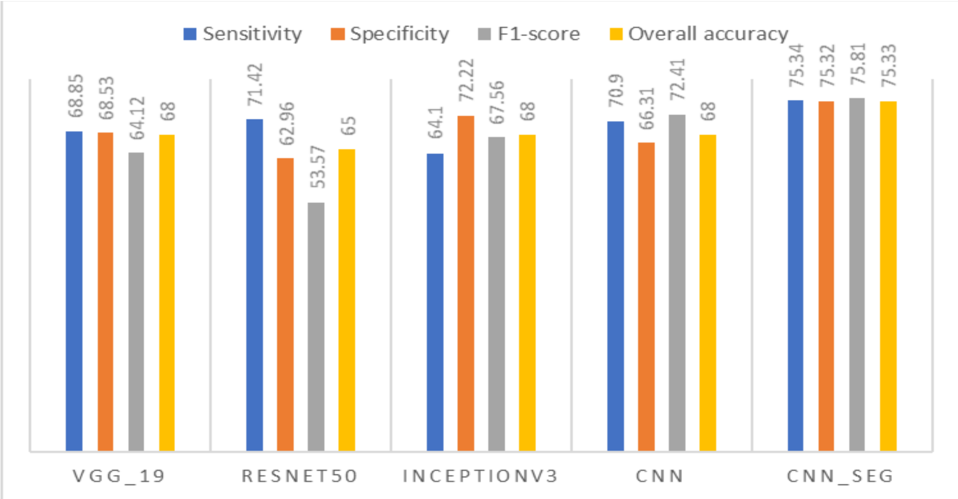

Fig. 9. Comparison of different networks with Proposed CNN for classification of COVID-19.

Comparison of proposed model with existing CNN models is shown graphically in figure 9. The proposed CNN has achieved f1-score of 72.41% which is higher than existing models such as VGG_19, ResNet50 and InceptionV3 with f1-scores of 64.12%, 53,57% and 67.56% respectively.

5 Conclusions and Future scope

The Coronavirus disease (COVID-19) is an infectious disease, by which world is facing global public health crisis since the year 2019. As per July 2021, millions of people are affected by COVID-19 worldwide. Along with the most usual symptoms of COVID-19 such as cough, shortness of breath and fever, the COVID-19 infected patients will also suffer from Pneumonia. In this study, we develop a framework to automatically segment and classify COVID-19 CT images using K-means clustering and proposed convolutional neural network. After training the proposed network with segmented images using K-means clustering, the accuracy is high compared with proposed network trained with original images. The accuracy of the proposed CNN trained with segmented images is also high when compared with pre-trained models such as VGG19, InceptionV3 and ResNet50.

Therefore, CNN with fewer layers perform better than pre-trained complex networks thereby reducing computational time. Since a small set of data is used in the experiment for training the proposed model, the future direction is to use large quantity of training data to improve the accuracy of the model and to increase the number of output classes.

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