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Real Time Recognition of Face Covered with Facemask using CNN for Application in Classroom Attendance System

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ABSTRACT

Because each person has a different face identity, facial recognition relies on the distinctness of individual facial traits. However, the recent Covid-19 pandemic has substantially altered daily living, required the usage of facemasks while walking outside, including for educational activities such as attending lectures at schools and universities. Facemasks' widespread use presents a significant problem to facial recognition systems since they obscure a significant area of the face, limiting the availability of important facial clues. In response to this critical issue, this project aims to create a Convolutional Neural Network (CNN) architecture suitable for use in a classroom attendance system. The research process begins with the creation of a large training dataset that includes five different students with four different facial circumstances, including facemask covering. The best CNN design is determined through painstaking testing to enhance accuracy during both the training and validation phases. The empirical findings demonstrated that the finalized CNN architecture has a remarkable validation accuracy of up to 96.2%. The trained system demonstrated outstanding precision in recognizing persons during real-time recognition tests. This experiment highlights the CNN's ability to recognize students with high accuracy even while they are wearing facemasks, indicating its potential in solving the issues provided by the prevailing public health measures.

1. Introduction

Face recognition has been one of the most used technologies of human interaction [1-2]. In modern days, the application of face recognition technology can be found everywhere such as in smart phones, building security, websites, and ATM machines [3-7]. It is also currently one of the more secure ways to replace the typical id verification such as using alphabetical password [8,9]. The history of face recognition technology is exceptionally long and based on this project literature study, it started back to the year of 1871, as reported by Adjabi *et al.,* [10]. Since that, there are many

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techniques of face recognition that have been developed and artificial intelligence has dominated the technology [11].

Convolutional neural network (CNN) is a type of artificial neural network which specialized in analyzing visual image [12]. In general, the architecture of CNN consists of two main structures; the feature extraction layers and the classification layers [13,14]. In the main feature extraction layer, it has the input, convolution layers and the pooling layers. The next layer of the CNN consists of fully connected layers and the output. The input dataset is the image that the CNN will train and validate while the convolution layer is where the detail features of the images will be processed and extracted. Next, the pooling layer, in which it will reduce the size and the position of the images to help for a better prediction to be made. The Rectified Linear Unit (ReLU) layer functions as the activation function for the CNN, and its output can be form as $f(x) = \max(0, x)$. The fully connected layer forms a vector which connects all the features involved so that the output can make the prediction [15]. This type of neural network was discovered by Lechun *et.al* [16] in 1989. They developed LeNet-5 which consists of two hidden layers with two ReLU. The input dataset used are characters of 0-9 with the total of 1000 samples. Each of the samples are 32 x 32 in size. They also tested their CNN using image of unusual and distorted numbers.

In the late 2019, Covid-19 virus has shocked the world. To prevent from getting infected, people all over the world are forced to obligate to cover some part of their face whenever they go to the public places or outside of their house. The main part of the face that need to be covered is nose and the mouth. During this time, the usage of fabric-based facemask can help to reduce the risk of someone spreading or getting the virus from others [17-20]. However, wearing a facemask covers many key features of our faces. The major features that will be covered by the facemask is the nose and the mouth. Therefore, recognition of people by visual sometimes become particularly challenging [21].

During this period, schools, universities, and many other institutions where taking classroom attendance is necessary has faced problem to recognize students. In some places, to follow the requirement of always wearing facemask and at the same time to easily identify students, lecturers are forced to develop their own reliable system that can be used to overcome this problem.

The objective of this paper is to discuss the design of CNN algorithm that can be used in classroom for the attendance system and students' recognition. This tool can be used for taking attendance record even if the students are covering their face with the facemask. Even though key features are covered, there are other part of faces that still can be identified using this artificial intelligence technique. MATLAB software is the platform that we applied for the design of the algorithm as well as for the real time recognition. This is due to the availability of MATLAB software in the classroom pc and easy to operate. The highest accuracy of CNN architecture will be tested for real time face recognition through web camera. The overview of CNN model is shown in Figure 1.

2. Methodology

There are three steps were taken when designing the face recognition system in Matlab software for the attendance system. The first step will be the preparation of the students' image database for the purpose of training and validation. For the purpose of this study, the number of students we set to five. For the real application, the number of the student will follow the total student in that class. This will be followed by the design and validation of the CNN algorithm using MATLAB software. Lastly, real time face recognition for final validation will be carried out to see the ability of the developed system to recognise the students.

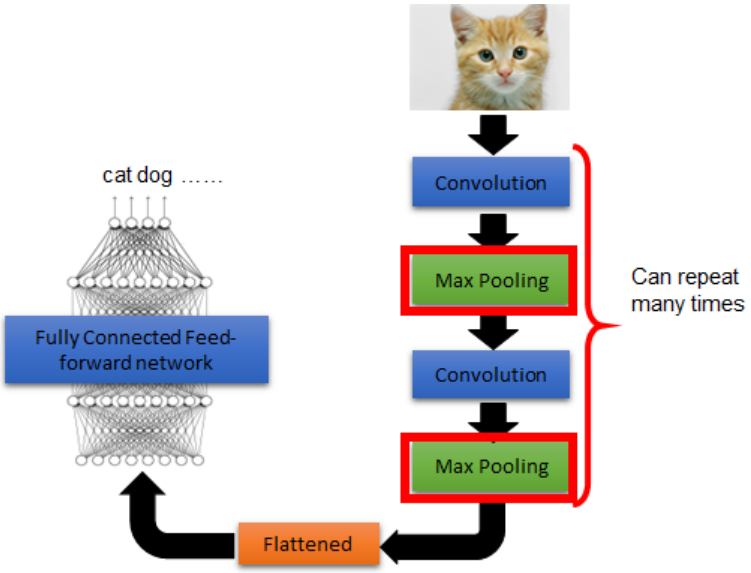

Fig. 1. The overview of CNN model

2.1 Image Dataset Preparation

Dataset is the input for training the CNN algorithm. The dataset consists of images of faces. There are five students' faces used for the classification whereby each face contains four types of different face images. The purpose of using several types of facemasks is because there will be an absolute possibility of students coming to the classroom with several types of facemasks. The four types of faces are (a) Face without facemask, (b) Face with transparent facemask (This type of facemask will make the mouth visible), (c) Face with light colour facemask and (d) face with dark colour facemask. Figure 2 shows an example of images of a student with different appearance. Based on this figure, over 50% of the face features are covered by the facemask. For each of the five images, 100 samples were prepared. All samples were taken with random changes in some angle. The total of the sample image is 500 for each of the students. Every sample was edited to reduce noise i.e., the unwanted background and lighting. In MATLAB, all images need to be saved in different folders according to the number of the classification. With some consideration in terms of processing time and storage, the size of all digital images was automatically adjusted to the size of 270 x 220. This size was chosen as it shows that considerably high accuracy can be achieved with it. In terms of the quality of images, it was set to the standard quality.

Fig. 2. Sample of images when facemask is not covered and covered (with different type of facemask)

2.2 CNN Algorithm Design

The CNN algorithm was developed for the face recognition using Matlab software. To start the process of developing the CNN algorithm, the LeNet-5 based architecture was applied. The algorithm

was first trained and tested for recognizing images of two different people. The total of the samples used in this stage was 200 images, with 100 sample images for each person. The algorithm for this image recognition consists of architecture as listed in Table 1. The feature extraction layer consists of two convolutional layers, and one fully connected neural network layer. The first convolutional layer was set to have 6 filters with the size of 5 x 5 and maximum pooling function was used for the selection. In the second layer, number of filters was increased to 16 filters with the size was remained the same of 5 x 5. The objective of this stage is to apply CNN in classifying two people with facemask on their face. The simulation result will be discussed in the next section.

Table 1
Initial CNN architecture

No	CNN Layers	Details
1	Image input	270 x 220 x 3
2	Convolution layer	6 filters; 5 x 5
3	ReLu	
4	Max pooling	2 x 2
5	Convolution	16 filters; 5 x 5
6	ReLu	
7	Max pooling	2 x 2
8	Fully connected layers	
9	Softmax	
10	Classification	

Next, the number of people for the CNN algorithm to classify was increased. The number of people is set to five. The same combination of images with and without facemask was used as training and validation dataset. First, the same CNN algorithm, as listed in Table 1 was applied for the classification. Validation accuracy for this new dataset seems to be drastically reduced to less than 50%. This result shows that the algorithm needs to be improved for classification of more input dataset. To improve the performance of the algorithm, there are several components of the algorithm were to be reconsidered, namely the hidden layer structure (convolutional and pooling layer), number of filter and the stride. Table 2 shows the improved algorithm for classification of 5 people dataset.

Table 2
Final CNN architecture

No	CNN Layers	Details
1	Image input	270 x 220 x 3
2	Convolution layer	32 filters; 5 x 5 x 3
3	ReLu	
4	Max pooling	2 x 2
5	Convolution	64 filters; 5 x 5 x 6
6	ReLu	
7	Max pooling	2 x 2
8	Convolution	128 filters; 5 x 5 x 6
9	ReLu	
10	Max pooling	2 x 2
11	Fully connected layers	
12	Softmax	
13	Classification output	

It can be seen from Table 2 that increment in hidden layer was required for the higher number of input dataset. Instead of 2, the hidden layer has increased to 3. The number of filters at each hidden layer has also been increased to 32, 64 and 128 for all the 3 hidden layers. In terms of the percentage of images using for training and validation, the simulation was set to have 80% of images for training and 20% used for the validation purpose. The learning rate of the CNN was set to 0.0001. After the training and validation of the algorithm was completed, the algorithm was tested for the real time face recognition through web camera.

3. Results

There are two main results that will be discussed. One is the results for the face recognition of two categories of datasets, and the other is the results of the face recognition of five categories of datasets. The accuracy of validation from the simulation is given by Eq. (1).

$$\text{Accuracy percentage} = \frac{number\ of\ correct\ prediction}{total\ number\ of\ prediction\ made} \tag{1}$$

Based on the initial simulation conducted for the face recognition of two categories of people, the initial accuracy prediction result obtained was about 53%. At this point, the max pooling stride value was set to 1. The prediction result is incredibly low. A new attempt to achieve a higher prediction percentage was done by increasing the number of filters of the convolution layers and the stride number of the max pooling. The filters were set to 32 for the first hidden layer and 64 for the second hidden layers. The stride value then was set to 3. Based on this configuration, the validation percentage increased to about 97%. At the same time, the live face recognition shows a high accuracy. This result can be seen in Figure 3. From this figure, the prediction level is equals to one. This means that the probability of recognition is 100%.

Let us look at the classification results for five categories of people. When the same configuration was used, the result of validation fell to about 42%. It shows that increment in the classification categories affects the validation accuracy. Therefore, revision in the CNN algorithm needs to be done so that it can give better validation accuracy. Based on the revised CNN algorithm in Table 2, the training and validation of the algorithm was carried out.

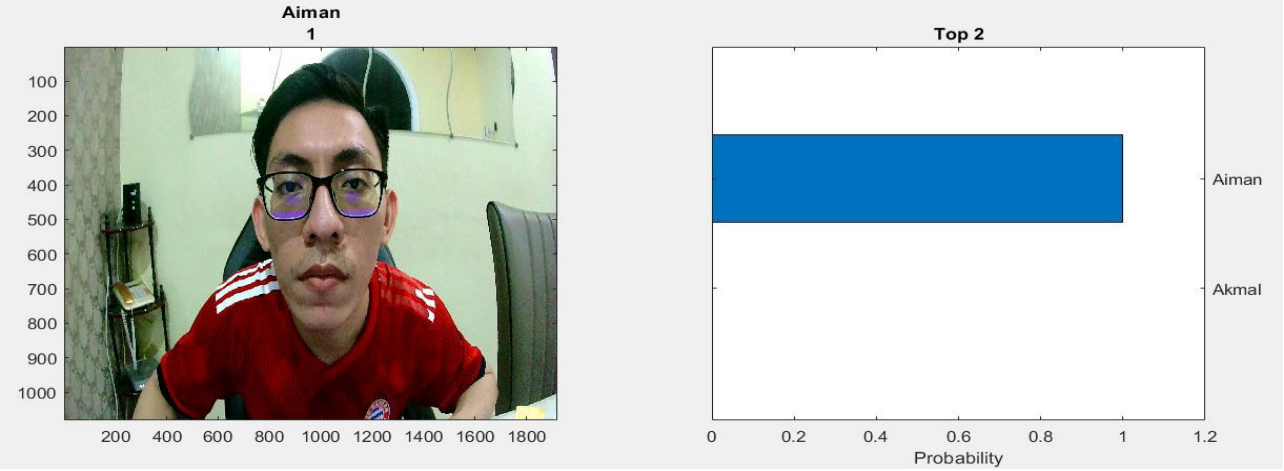

Fig. 3. Real time face recognition with 2 different students

Table 3 shows the results of the simulation. Variation in the number of maximum epochs gives different validation accuracy. It is obvious based on this table that the validation accuracy for five

categories of people increased up to about 96% when value of maximum epoch was up to a certain level. When number of epochs is increased to 28, the validation accuracy reduced to 95%. This can be thought as the overfitting problem that caused the declining. Based on the proposed design, the highest accuracy for validation process is 96%.

In terms of accuracy of real time face recognition, the accuracy is also remarkably high. This can be viewed in Figure 4. The accuracy level for the live recognition were 90% for face covered by black facemask, 87% for the face covered by transparent mask, 95% for uncovered face and 98% for face covered by the white colour facemask. These results show that the CNN algorithm can be designed and applied for the face recognition for both the covered and uncovered face effectively.

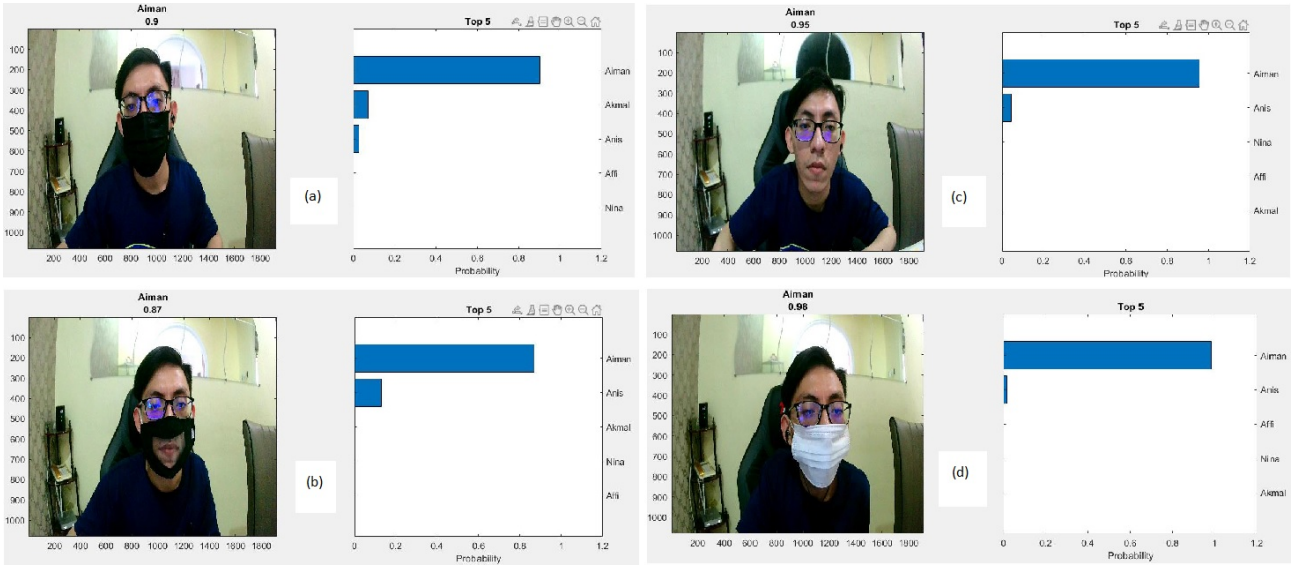

Fig. 4. Real time face recognition using when (a) black facemask is ON (b) transparent facemask is ON (c) face is uncovered and (d) white facemask is ON

Table 3
Prediction accuracy

No.	Maximum epoch	Validation accuracy
1	5	66%
2	8	70%
3	10	80%
4	12	88%
5	15	94%
6	25	96%
7	28	95%

4. Conclusions

In this paper, we developed a CNN architecture using Matlab software for recognition of students who wearing facemask for the application in the attendance checking system. We evaluated and analysed the structure of CNN to classify five distinct categories of students to achieve the highest accuracy in training and validation. The performance of developed CNN achieved up to 96.2% validation accuracy. The trained system predicted correctly for all the different type of faces in real time recognition as well as when it was test using web camera. It is concluded that the performance of CNN in face recognition is highly accurate even people cover their face with facemask and suitable for the application in the classroom attendance system.

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