



Face Mask Detection Using GoogLeNet CNN-Based SVM Classifiers

Kubilay Muhammed SUNNETCI^{1,3*} , Selahaddin Batuhan AKBEN¹ , Mevlude Merve KARA^{1,2} , Ahmet ALKAN³ 

¹Osmaniye Korkut Ata University, Faculty of Engineering, Department of Electrical and Electronics Engineering, 80000 Osmaniye, Turkey

²Osmaniye Korkut Ata University, Faculty of Engineering, Department of Energy Systems Engineering, 80000 Osmaniye, Turkey

³Kahramanmaraş Sütçü İmam University, Faculty of Engineering, Department of Electrical and Electronics Engineering 46050, Kahramanmaraş, Turkey

Highlights

- This article focuses a system that can automatically detect whether people are wearing masks.
- A face mask detector is proposed using a hybrid of deep learning and machine learning techniques.
- The proposed system is effective and sufficient in terms of classification performance metrics.

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Abstract

The COVID-19 pandemic that broke out in 2019 has affected the whole world, and in late 2021 the number of cases is still increasing rapidly. In addition, due to this pandemic, all people must follow the mask and cleaning rules. Herein, it is now mandatory to wear a mask in places where millions of people working in many workplaces work. Hence, artificial intelligence-based systems that can detect face masks are becoming very popular today. In this study, a system that can automatically detect whether people are masked or not is proposed. Here, we extract image features from each image using the GoogLeNet architecture. With the help of these image features, we train GoogLeNet based Linear Support Vector Machine (SVM), Quadratic SVM, and Coarse Gaussian SVM classifiers. The results show that the accuracy (%), sensitivity (%), specificity (%), precision (%), F₁ score (%), and Matthews Correlation Coefficient (MCC) values of GoogLeNet based Linear SVM is equal to 99.55-99.55-99.55-99.55-99.55-0.9909. When the results of the proposed system are examined, it is seen that it provides an advantage due to its high accuracy. In addition, it is very useful in practice that it can detect masks from any camera. Moreover, since there are classification models that can be created in a shorter time than models that can detect objects, model results can be examined in a shorter time. Therefore, it is seen that the proposed system also provides an advantage in terms of complexity.

1. INTRODUCTION

Due to the COVID-19 disease, approximately 249 million coronavirus cases have been detected since 2019 [1]. In addition, we know that the number of infected is increasing day by day. Herein, it is known that some of the most important factors preventing the spread of the disease are wearing face masks and complying with the cleaning rules [2]. As a result of this disease, the use of the mask can prevent the spread of coronavirus disease. However, due to the large number of people that wear the mask, manual face mask detection is costly and difficult. Therefore, there are many studies in the literature on this subject.

In the literature, the proposed system is a real-time system that can be used in airports, train stations, schools, etc., due to the outbreak of COVID-19. In the system, which consists of two stages, Phase-1 and Phase-2, the face mask detector is trained first. Afterward, the real-time application of this system is designed [3]. One of the aims of the study is to develop an artificial intelligence algorithm that identifies the person without a face mask. In addition, it is aimed to detect unmasked persons over a video using this developed system. From the results, it is seen that people wearing and not wearing masks can be successfully detected [4]. A system has been proposed to detect persons not wearing masks. Here, using the Mobilenetv2 architecture, it is determined whether people wear masks [5]. Models capable of detecting face masks have been created using some transfer and deep learning methods. The results show that the ResNet50v2 and Xception architectures are better than MobileNetv2 in terms of accuracy and precision [6]. A machine learning and image processing-based system has been proposed to detect whether people are masked or unmasked. Similarly, the results show that this case has been detected successfully [7]. A deep learning-based face mask detector is proposed to achieve low computational requirements and high performance. At this point, it has been seen that the proposed system has a high potential to combat the coronavirus epidemic [8]. It is aimed to attract the attention of researchers by examining many studies on face mask detection in this study. Accordingly, the performance values obtained for different algorithms were compared. In addition, the study has concluded by discussing some difficulties in this field and the future of the subject [9]. It is intended to annotate and localize face masks from real-life images. Here, the proposed system first extracts the image feature using the ResNet-50 architecture. Afterward, face mask detection is performed using YOLO v2. The results show that the highest average precision has reached 81% [10]. After detecting human subjects in videos, a system is proposed that can detect whether people are wearing masks using a system that can detect human faces. The results show that the F_1 score and recall values of the proposed system are 87.7% and 99.2%, respectively [11]. The proposed system uses TensorFlow, Keras, and OpenCV, and deep learning to detect face masks. The accuracy obtained using Shot Multibox Detector and Mobilenetv2 in the study is equal to 92.64% [12]. In this study, they have examined to find the best model among the three classifiers that detect whether people wear masks. From the real-time results, it appears that the best model is MobileNet, with an accuracy of 94.2% [13]. A method using a Raspberry-PI camera that captures live streaming video and processes this data is proposed. In addition, the proposed system has been designed using a toll-way gate that allows only mask-wearing people to enter. The results show that the accuracy of the proposed system is equal to 96% [14]. After training 4000 epochs of a system that can detect face masks using YOLOv3, a real-time application of this system is designed. According to the experimental results, it has been observed that the proposed system reached 96% classification accuracy [15]. This article has used ResNet-101 Convolutional Neural Network (CNN) architecture with 101 layers of depth to detect masked and unmasked people. From the results, it is seen that the accuracy of the proposed model can reach 96.02% [16]. Using deep learning techniques, a system has been developed that checks whether the person is wearing a face mask and whether he or she complies with the physical distance. The number of images used in the study is equal to 20000, and it is seen that the training accuracy of the model created by cropping in 224*224 pixels is equal to 97% [17]. OpenCV, PyTorch, and deep learning have been used to develop a face mask detector that can detect whether a person is wearing a mask. Here, it has been observed that the model created using ResNet reached 97% validation accuracy [18]. A real-time system is proposed that can classify masks, hand shields, sunglasses, and glasses detection with the help of the same model. The results show that the proposed system can reach 97.2% accuracy [19]. A two-stage face mask detection system is proposed in this study. Here, after determining the Region of Interest (ROI) of the person, a system has been developed that can detect whether people are masked or unmasked. From the results, it is seen that the accuracy of the proposed system can reach 98% [20]. In this study, a face mask detection system and a convolutional neural network-based method that notifies people who do not wear masks are proposed, and the proposed system runs in real-time. From the results, the accuracy of the proposed trained model is equal to 98% [21]. This article proposes a real-time technique that can detect unmasked people to contribute to public health. This technique is the ensemble of one-stage and two-stage detectors. The proposed system has achieved 98.2% accuracy using the ResNet50 network [22]. A model has been developed that can detect whether a person is wearing a face mask using Facemasknet, a deep learning technique. There are three classes here, wearing a mask, improperly worn masks, and no mask detected. The results show that the accuracy of the proposed system is equal to 98.6% [23]. It is aimed to automatically detect face masks in videos in this study. After detecting the face, MobileNetv2 architecture has been used to determine the mask area. According to the

results, the training and validation accuracy values of the proposed model are equal to 99.2% and 99.8%, respectively [24]. A hybrid model has been developed by using deep learning and machine learning in this study. First, the ResNet50 architecture is used to extract image features. Afterward, images are classified using SVM. The results show that the proposed system achieves 99.64%, 99.49%, and 100% test accuracy for different dataset [25]. A system capable of detecting face masks with extremely low memory is recommended. Here, they have used an ARM Cortex-M7 microcontroller clocked at 480 Mhz and having just 496 KB of frame buffer RAM. From the results, it is seen that the test accuracy of the proposed system is equal to 99.83% [26]. A technique that can be used on Internet-of-Things (IoT) devices has been developed for face mask detection and reminder, and this technique uses MobileNetv2, Inceptionv3, VGG 16, and ResNet50 architectures. The results show that the most successful system is VGG 16 and its test accuracy is 99.87% [27]. It is aimed to comprehensively investigate the use of existing artificial intelligence technologies to detect face masks. Here, it is seen that architectures such as Inceptionv3 can reach 99.9% accuracy in face mask detection [28]. On the other hand, artificial intelligence technologies can be applied to almost every field today [29–33]. It is known that the face mask can be detected easily and automatically with the help of artificial intelligence technologies. It is aimed to design a reliable system thanks to the proposed system in which fewer images are used instead of many images, and its training time is quite fast.

In this study, the face mask is detected using images taken from 220 masked and 220 unmasked people. Here, deep image features are extracted from the images used in the study using GoogLeNet deep learning architecture. Since we get the deep image features using the loss3-classifier layer of GoogLeNet architecture, we obtain 1000 deep image features from each image. After extracting the deep image features, we train GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers. Then, with the help of trained models, we design a GUI application of the proposed system and a system that can detect whether people have masks according to the snapshot.

In the light of this information, this study is innovative and competitive for the following reasons:

- Successfully detecting whether the person is wearing a mask with high accuracy and other performance metrics brings the study to the fore. Herein, a high-performance study for the dataset used in the study is presented.
- On the other hand, we propose a classification model that is relatively less complex than models capable of object detection.
- It is also seen that the time spent in the training, validation, and testing phases is saved.
- Thanks to the proposed system, mask detection is performed with both live cams and a GUI application. Here, the purpose of using the GUI is to be able to see the errors that may be caused by live cams. Thus, the performance of the proposed systems can be seen more clearly. In practice, mask detection using live cams is more useful.

2. MATERIALS

In this section, we present the dataset used in the study, which can be easily accessed from the publicly available open access repository on a website [34]. Here, there are images taken from 220 masked and 220 unmasked people. In addition, the file type of the images used in the study is PNG. Herein, we extract deep image features from a total of 440 images using the GoogLeNet deep learning architecture. The extracted 1000 deep image features are then applied to the inputs of the different SVM classifiers using the 10-fold cross-validation technique. To better understand the dataset used in the paper, we give the statistics of the number of images in each class as in Table 1.

Table 1. Number of images found in each class

	Dataset Size	Cross Validation
With mask	220	10-fold
Without mask	220	
Total	440	

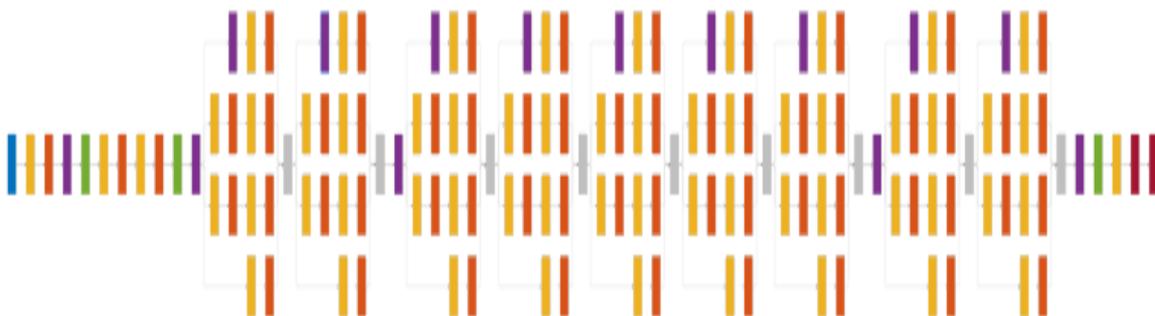
The pixel values of these images with 24 or 32-bit depth are different. These images were obtained both from real life and from the internet (from different camera or internet). So, the proposed system is available for all conditions, not just specific ones. Already, it has been seen that the proposed method can successfully detect masked people in different environments during the phase. Therefore, the data set used in the study is suitable for the solution of the problem.

3. METHOD

In this study, we determined whether there is a face mask by using images taken from people. Half of the 440 images in the study are with mask images, while the other half are without mask images. Herein, we extract deep image features from a total of 440 images using the GoogLeNet deep learning architecture. In addition, a total of 1000 deep image features are extracted from each image by using the loss3-classifier fully connected layer of the GoogLeNet architecture. Therefore, we can train Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers using these obtained image features and the 10-fold cross-validation technique. We chose the SVM classifier because it has higher success than other classifiers for this study. Eventually, we designed a GUI application to detect the existence of a face mask without the need for humans using these trained classifiers.

3.1. Feature Extraction

The network structure of the GoogLeNet deep learning architecture used in the study is given in Figure 1. GoogLeNet is a convolutional neural network with 22 deep layers. Like other convolutional neural networks in MATLAB, it can classify images up to 1000 categories. Additionally, for this classifier to be used in MATLAB, the image input has the size of 224-by-224. GoogLeNet deep learning architecture that consists of 144 layers in total have image input, convolution, ReLU, pooling, cross channel normalization, depth concatenation, dropout, fully connected, softmax, and classification output layers [35, 36]. We can explain this by using different colors as in Figure 1. Here, layers 140-143 are pool5-7x7_s1, pool5-drop_7x7_s1, loss3-classifier and prob, respectively. GoogLeNet extracts the deep image features of $1*1*1024$, $1*1*1024$, $1*1*1000$, and $1*1*1000$ dimensions, respectively. Although different image features can be extracted from each layer in GoogLeNet deep learning architecture, we extracted 1000 deep image features from each image using the loss3-classifier layer. Herein, different deep image features can be extracted from different layers, but it is useful to determine the most appropriate layer to extract these image features.

**Figure 1.** Network structure of the GoogLeNet architecture

3.2. Classification and GUI Application

SVM classifiers are one of the widely used supervised classifier algorithms that were proposed in the 1990's. This classifier has been widely used in artificial intelligence techniques developed for signal processing and image processing from past to present. The main idea of SVM classifiers is to find the optimal hyperplane [37]. Herein, SVM classifiers can vary according to kernel functions and can be applied to different data structures. Since GoogLeNet based deep image features are classified using Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers (they outperformed other kernel functions for this study), we give the block diagram of the proposed system as follows:

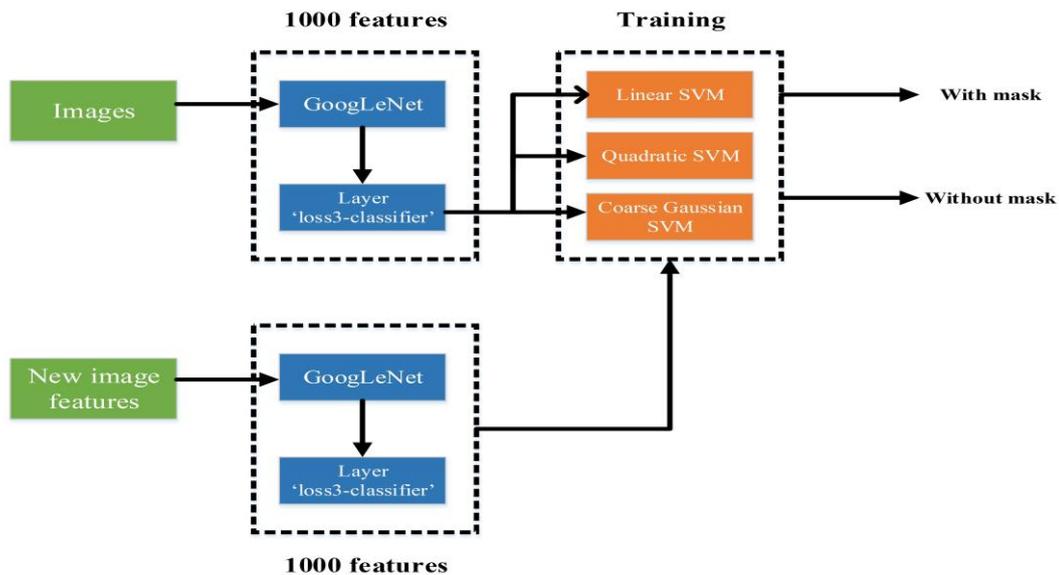


Figure 2. Block diagram of the proposed system

The block diagram of the whole proposed system is given in Figure 2. Here, all images in the dataset are imported into the GoogLeNet deep learning architecture. Using the loss3-classifier fully connected layer in the 142nd layer of GoogLeNet deep learning architecture, 1*1*1000 deep image features are obtained for each image. Employing the obtained image features, Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers are trained, and a 10-fold cross-validation technique is used here. Three different trained SVM classifiers were saved to the computer as the trained models. Then, using trained models, we can detect automatically whether people have masks by employing snapshots or images. Therefore, we designed the GUI application of the proposed system. Here, new image features need to be installed by the user. These image features must be obtained with the help of GoogLeNet deep learning architecture. To examine the classification performance metrics and training parameters of the classifiers used in the study, we give Table 2 as follows:

Table 2. Some classification performance metrics and training parameters of the classifiers used in the study

GoogLeNet	Accuracy (%)	Total Misclassification Cost	Detection Duration (~obs/sec)	Training Time (sec)	Model Type
Linear SVM	99.5	2	600	14.86	Kernel function: Linear
Quadratic SVM	99.5	2	660	18.987	Kernel function: Quadratic
Coarse Gaussian SVM	99.5	2	680	27.644	Kernel function: Gaussian

Table 2 shows some classification performance metrics and training parameters of GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers used in the study. According to the table, it is seen that the accuracy of GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers are equal to 99.5%. Likewise, the table shows that the total misclassification cost values are equal to 2 for all three classifiers. In this case, GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers used in the study are the same as each other in terms of accuracy and total misclassification cost. However, we should examine the classification performance metrics separately according to the prediction errors in the positive and negative classes. Kernel functions used by GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers are determined as Linear, Quadratic and Gaussian, respectively. Also, the prediction speed (\sim obs/sec) and training time (sec) values of Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers are equal to 600-660-680 and 14.86-18.987-27.644, respectively. When these classifiers are compared with each other in terms of prediction speed and training time, it is seen that the most successful systems according to prediction speed and training time are Coarse Gaussian SVM and Linear SVM, respectively. Afterward, a GUI application was designed, and here we use the GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers.



Figure 3. Screenshot of the GUI application of the proposed system

Trained models used in the GUI application can also easily detect whether people are masked according to snapshots. In the designed GUI application, the image is loaded to the application by the user utilizing the Load Image button. Here, after deep image features are extracted by GoogLeNet deep learning architecture, Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers detect whether people are masked or not. To show this situation, we applied to the images of a masked and unmasked person as in Figure 3a-b. From Figure 3a-b, it is seen that an unmasked person is correctly detected without a mask, and a masked person is correctly identified as a masked person. Here, the application prints on the screen 'without mask' using red color. Similarly, 'with mask' is printed on the screen using green color for masked persons. On the other hand, face mask detection of images obtained from snapshot according to Linear SVM classifier is given in Figure 4a-b.



Figure 4. Face mask detection from snapshot using Linear SVM classifier

4. EXPERIMENTAL RESULTS

Confusion matrices and Receiver Operating Characteristic (ROC) curves for GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers used in the study are given separately in this section, and we train these classifiers using 10-fold cross-validation. Thus, we can easily calculate classification performance metrics for the classifiers used in the study. Firstly, we render the confusion matrices and ROC curve for the Linear SVM classifier used in the study as follows in Figure 5.

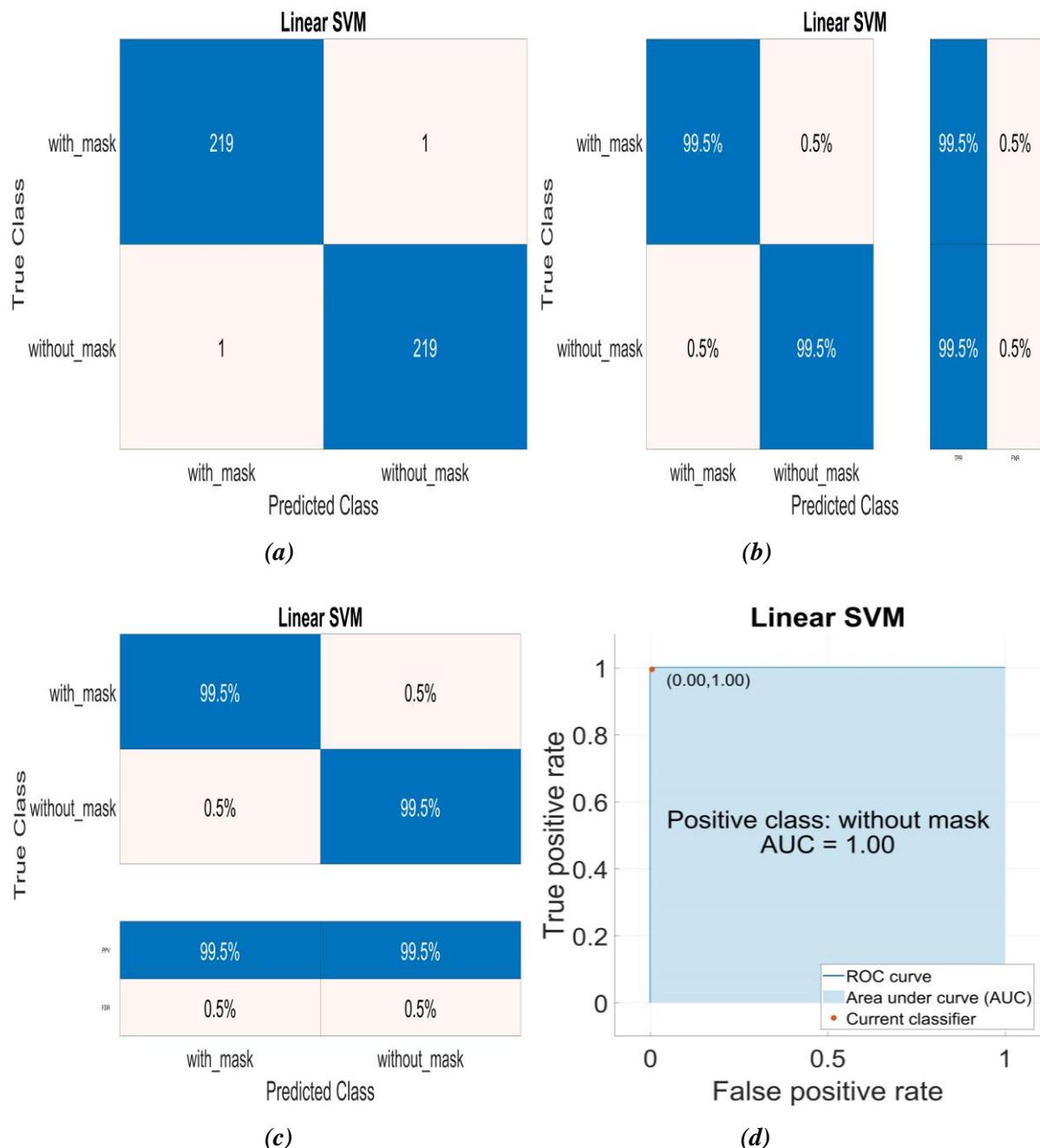


Figure 5. Confusion matrices and ROC curve of the Linear SVM classifier used in the study

Figure 5 shows the confusion matrices and ROC curve of the Linear SVM classifier. Figure 5a-d shows the confusion matrix (number of observations), True Positive Rate (TPR)-False Positive Rate (FPR), Positive Predictive Values (PPV)-False Discovery Rates (FDR), and ROC curve for positive class: without mask, respectively. From Figure 5a, we can see that 438 out of 440 images were predicted correctly. It is also seen that while TPR and PPV values are equal to 99.5% for with mask and without mask, FNR and FDR values are equal to 0.5%. From Figure 5d, it can be seen that the Area Under Curve (AUC) value for the positive class: without mask is equal to 1.

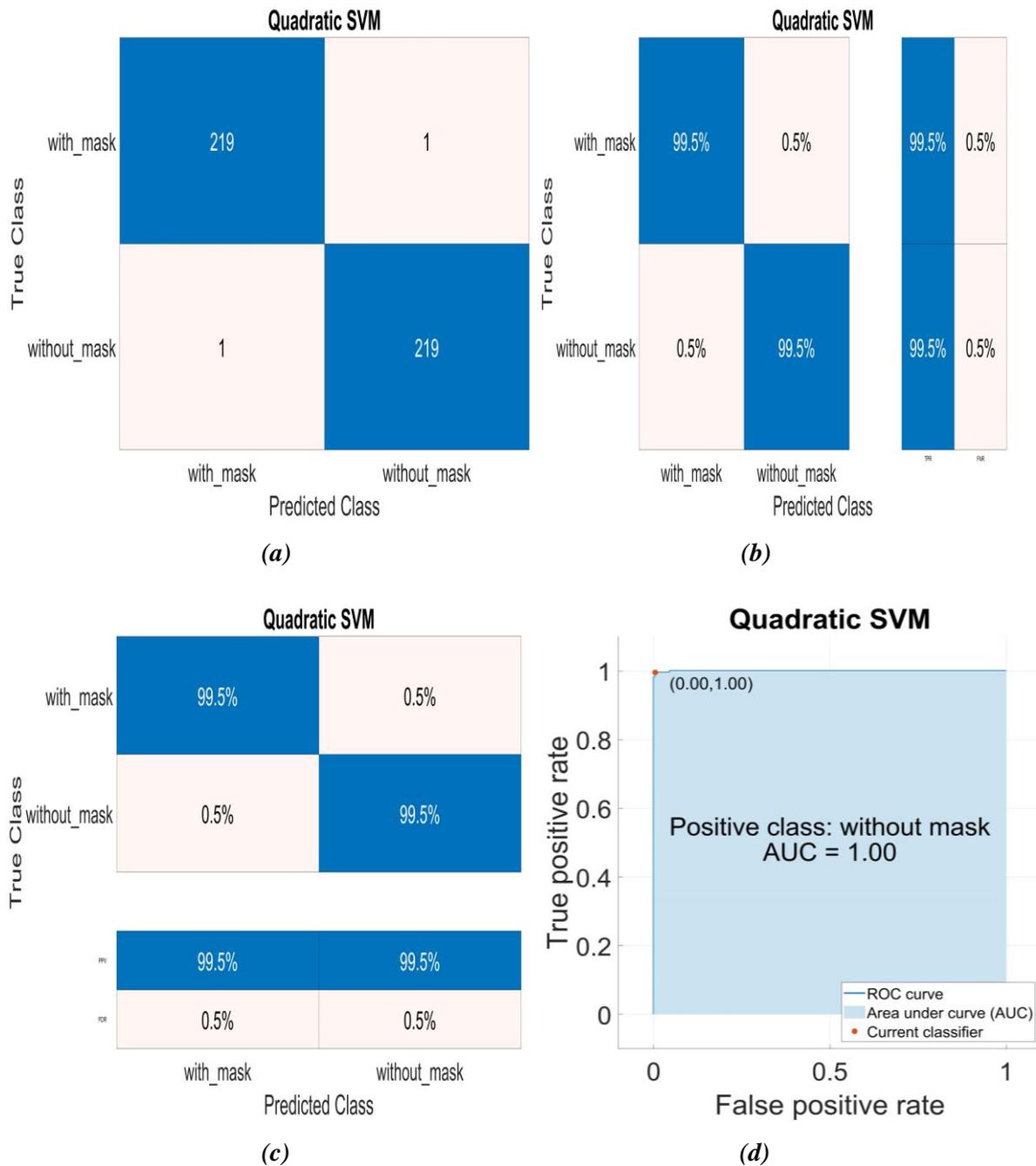


Figure 6. Confusion matrices and ROC curve of the Quadratic SVM classifier used in the study

Figure 6a-d shows the confusion matrix (number of observations), TPR-FPR, PPV-FDR, and ROC curve for Quadratic SVM classifier, respectively. As in Linear SVM, we can see that TPR-PPV, FNR-FDR, and AUC values in the Quadratic SVM classifier are also equal to 99.5%, 0.5%, and 1, respectively.

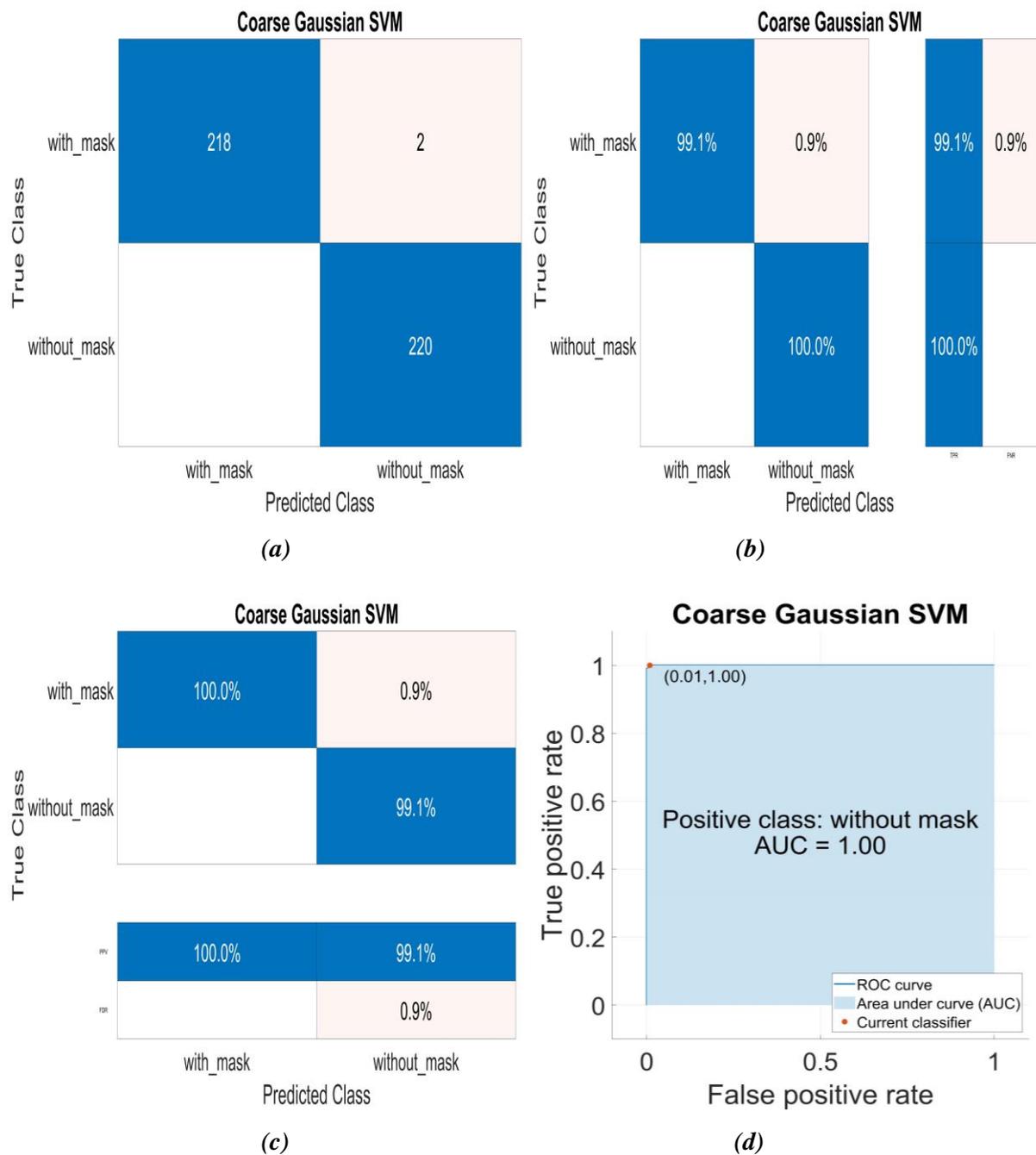


Figure 7. Confusion matrices and ROC curve of the Coarse Gaussian SVM classifier used in the study

Figure 7 shows the confusion matrix (number of observations), TPR-FPR, PPV-FDR, and ROC curve for the Coarse Gaussian SVM classifier. As seen in Figure 7, 220 people without masks were estimated as unmasked, while two people with masks were estimated as unmasked. From Figure 7b-c, it is seen that TPR-PPV values for with mask are equal to 99.1% and 100%, respectively, and these values are equal to 100% and 99.1% for without mask, respectively. When we examine Figure 7d, we see that the AUC value is equal to 1. Therefore, we can understand that the created models can successfully classify.

5. DISCUSSION

In this paper, we determine whether people are masked by using deep learning and machine learning methods. There are 220 masked and 220 unmasked people in the dataset used in the study. Here, we do not directly use convolutional neural network models because the number of images in the dataset is small. Therefore, we extracted deep image features for each image used in the study using GoogLeNet deep

learning architecture. Herein, we extract 1000 image features for each image using the loss3-classifier layer of the GoogLeNet architecture. Afterward, we train GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifier using these extracted image features. In addition, we use the 10-fold cross-validation method for the created classifier models. Additionally, we design the GUI application of the proposed system so that users can utilize it easily. In addition, we design a system for this study that can detect whether people are masked from the live snapshot. To examine the classification performance metrics of the classifiers used in the study, we give Table 3 as follows:

Table 3. Classification performance metrics of the classifiers used in the study

GoogLeNet	Accuracy (%)	Error (%)	Sensitivity (%)	Specificity (%)	Precision (%)	F ₁ Score (%)	MCC
Linear SVM	99.55	0.45	99.55	99.55	99.55	99.55	0.9909
Quadratic SVM	99.55	0.45	99.55	99.55	99.55	99.55	0.9909
Coarse Gaussian SVM	99.55	0.45	99.09	100	100	99.54	0.9910

Table 3 presents classification performance metrics for GoogLeNet-based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers. Here, the accuracy (%), sensitivity (%), specificity (%), precision (%), F₁ score (%), and MCC of GoogLeNet-based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers used in the study are equal to 99.55-99.55-99.55, 99.55-99.55-99.09, 99.55-99.55-100, 99.55-99.55-100, 99.55-99.55-99.54, 0.9909-0.9909-0.9910, respectively. When we examine the table, we can see that all classifiers are the same in terms of accuracy. On the other hand, it is seen that Linear SVM and Quadratic SVM are better than Coarse Gaussian SVM in terms of sensitivity and F₁ score. In addition, the Coarse Gaussian SVM classifier is better than others in terms of specificity, precision, and MCC.

When the proposed system and the studies in the literature are compared, it is seen that the classification success of the proposed method is sufficient. Generally, 90% or more accurate is obtained in studies found in the literature [12-28]. Due to the low number of images in the dataset used in the proposed system, we do not use deep learning architectures to directly create the models. Instead, after extracting deep image features using GoogLeNet deep learning architecture, we detect whether people are not wearing masks with the help of GoogLeNet-based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM. Already, there are many systems that can be easily used in almost every field using artificial intelligence technologies [38-40].

Thanks to the proposed system, it can be easily determined whether people are wearing masks or not. Manual face mask detection is difficult and costly, especially when the COVID-19 outbreak spreads quickly and easily. Therefore, the developed proposed system can easily detect whether people are masked from both the designed user-friendly GUI application and snapshot. In addition, the proposed system will be developed and in future studies, it will be investigated whether the mask is worn correctly by focusing directly on the relevant region of the face.

6. CONCLUSION

In this study, we classify the 440 images found in the paper using images of masked and unmasked people. Using these images, we extract deep image features from the loss3-classifier layer of the GoogLeNet deep learning architecture. We get 1000 image features for each image in the dataset used in the study. Afterward, we train GoogLeNet based Linear SVM, Quadratic SVM, and Coarse Gaussian SVM classifiers using the obtained deep image features and 10-fold cross-validation method. Here, we propose a system that can detect the face mask from both GUI application and snapshot using trained models. Thus, we develop a system that can automatically detect whether people are masked or not. In this context, it is seen that the models used in this study provide advantages in terms of both high accuracy and complexity. In addition,

we determine whether the person is wearing a mask from the snapshot, since it is more convenient to detect masks using live cams in practice.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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