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M. S. I. Alsalamah
Department of Management Information System and Production Management, College of Business & Economies, Qassim University, Saudi Arabia, mslamh@qu.edu.sa

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Automatic Face Mask Identification in Saudi Smart Cities: Using Technology to Prevent the Spread of COVID-19

M. S. I. Alsalamah

Department of Management Information System and Production Management, College of Business & Economies, Qassim University, Saudi Arabia

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Abstract: The novel coronavirus that triggered the COVID-19 outburst is still active around the globe. By now, COVID-19 has affected practically every facet of progress, most importantly, it has shaken the healthcare system like never before. At its peak, it forced Governments throughout the world into lockdowns to limit the reach of the epidemic. Based on early advisories of the World Health Organization (WHO), the only method of safeguarding oneself from being infected was to wear a face mask. Even today, with fewer cases being reported, masking oneself remains the single most effective and cheap means of prevention. As urban areas continue to grow, effective city management is essential for mitigating the increase of the deadly COVID-19 disease. The success of smart cities depends on significant upgrades to public transportation, highways, companies, homes, and municipal streets. There is room for improvement in the public bus transportation system now in place, and one of those improvements would be to use artificial intelligence. To determine if the person is wearing a face mask, you need an autonomous mask detection and alert system. Therefore, this study introduced a deep learning-based design that combines the attention-based generative adversarial network (ABGAN) with the multi-objective interactive honeybee mating optimization (MOIHBMO) approach to create an automated face mask recognition system. A set of 1386 images has been used to create a real-time dataset. This database contains 690 pictures without face masks and 686 images with them. The suggested algorithm ABGAN-MOIHBMO is compared to other traditional methods for detection of face masks, such as DL, AI, and DNN. The performance indicators used are error rate, inference speed, precision, recall, accuracy, and over fitting assessments. The results demonstrate that the proposed ABGAN-MOIHBMO outperforms the existing methodologies. It provides 96% of precision, 86% of recall, 93% for the f1 score, which are higher/better than the other, traditional methods. The error rate in ABGAN-MOIHBMO is a low 1.1%, which is lower other approaches. To predict and underline the significance of face mask use, the face mask detection technique may be employed in the future at Saudi airports, shopping centers, and other congested locations. On a larger platform, our research will be an effective instrument in helping many nations throughout the globe combat the rapid spread of this contagious illness.

Keywords: ABGAN, COVID-19, MOIHBMO algorithm, smart cities, transportation system.

1 Introduction

The WHO regarded COVID-19 as a rapidly growing pandemic in the early 2020s. Since its first reporting, it has posed a grave threat to people's lives everywhere. COVID-19 variations and mutations have made the problem worse in the present day. A great deal of intellectual input has been invested in arriving at appropriate procedures and measures to save oneself from this virus. In recent times, the Saudi Press Agency (SPA) reported that the Saudi Ministry of Interior set aside the many measures adopted earlier to stop the spread of COVID-19, wearing of face masks in enclosed spaces. However, citizens desirous of leaving Saudi Arabia still needed to take a third booster shot. Moreover, the new law does not extend to those who fall into certain age categories or who have received a Ministry of Health exemption from vaccination requirements [1].

Currently, WHO advises that people should use face masks to avoid the growth of viruses. In addition, it recommends that individuals should maintain a social distance of at least 2 meters from one another to prevent disease transmission from one individual to another. Businesses which provide public services demand that their clients should wear masks to use their services. Therefore, predicting adherence to face masks and controlling social distances have become an essential computer vision to assist the global society [2]. It is possible to effectively protect airborne viruses and particles from reaching another person's respiratory system by having that individual wear a facemask as it limits the viral load in the surroundings. Using a facemask is an example of an intervention that does not involve the use of pharmaceuticals and is a non-invasive, cost-effective technique for reducing mortality and morbidity caused by respiratory infections. Following

*Corresponding author e-mail: mslamh@qu.edu.sa

the outbreak of COVID-19, people in several nations have started wearing facemasks daily to decrease their exposure to airborne germs. This is done to protect them from getting sick [3]. In several nations, the rules require people to wear face masks whenever they are out in public. These regulations and legislations were drafted to respond to the meteoric increase in reported cases and fatalities across various regions. On the other hand, monitoring big groups of individuals in public places is getting increasingly challenging. So, this study endeavors to devise a method of automating the process of facial recognition [4].

The pandemic opened a new area of research and development for computer science: The development of new COVID-19 automatic detection methods and the separation of mask-wearers from those who are not are only two of the numerous study subjects that have evolved recently. Studies concentrate on several choices because early laboratory test outcomes sometimes contain inaccuracies and delays [5]. The pandemic has been creating difficult circumstances for people all over the world with fatalities being reported every day. Almost 16,207,130 confirmed infected cases, of which 648,513 result in death, have been reported since this article was written. According to the WHO, the most common symptoms of coronavirus infection include a high temperature, a dry cough, exhaustion, diarrhea, a loss of taste and smell. Those who rigorously maintain social segregation from one another and use a facial mask are more likely to stay safe of the disease. Regrettably, the fact that people do not follow these rules properly is helping to speed up the progression of this condition. Identifying those who violate the law and reporting them to the appropriate authorities can assist in putting a halt to the spread of the coronavirus. Because individuals need to incorporate their faces into digital photos and choose whether or not to wear a mask, face mask detection includes both detection and classification issues. As a result of the widespread usage of facial detection systems, the first aspect of this problem, face detection, was the subject of substantial research in computer vision research. A method that can be used to stop the virus from spreading further is outlined in this research. In real-time, the technique entails assessing whether a person maintains the appropriate social distance and dons a face mask in public areas [6]. This paper strives to critically analyze the obstacles and constraints to a transition and upgrading of such a concept for implementation in developing nations, starting with the framework of the Smart City paradigm as envisaged by the developed world. This study proposed an ABGAN-MOIHBMO approach to overcome the obstacles.

Related works

The study of Rahman et al. [7] proposed a strategy that restricts the spread of COVID-19 by recognizing and identifying facial masks in smart city systems where all public spaces are watched over by Closed-Circuit Television (CCTV) cameras. This would be done to limit the number of people who could be exposed to the virus. Using the city network, the appropriate authorities are alerted when a person is without a mask. Sanjaya and Rakhmawan [8] suggested an Internet of Things (IoT) -based Smart Screening and Disinfection Walkthrough Gate (SSDWG). The SSDWG was designed to do rapid screening, which includes calculating the subject's temperatures with a sensor that does not require physical contact and storing a record of the individual under suspicion for future monitoring and control. Their suggested screening tool added real-time deep learning algorithms for face mask detection and categorization. Furthermore, Vijitkunsawat and Chantngarm [9] demonstrated the detection accuracy of 3 deep learning face mask detection approaches: "Max pooling, Average pooling, and MobileNetV2 design". Das et al. [10] discovered and labeled the things in real-life images of medical face masks. Using a medical face mask in public spaces can help protect people from the Covid-19 disease, which can spread from person to person. There are two parts to the approach that is being offered. The essential component for the feature extraction technique was developed with the help of the ResNet-50 deep transfer learning strategy.

Yadav [11] analyzed the many artificial intelligence models utilized to identify face masks. Based on the research results, deep learning techniques like the Inceptionv3 CNN achieved an accuracy of 99.9% when detecting COVID-19 face masks. Negi et al. [12] described DL methods, TensorFlow, Keras, and OpenCV, a suggested process for recognizing face masks. Because it requires relatively few resources to be put into operation, this approach is suitable for goals related to safety. The Single Shot Multibox Detector is used as a face detector by the SSDMNV2 method, while the MobilenetV2 architecture serves as the classifier's structural framework. These two parts may be used in embedded systems to detect real-time masks because they are so small and light. Oumina et al. [13] presented a mask detector that uses a machine-learning face classification algorithm to identify mask wearers. Combined with a CCTV system, this detector can ensure that only people wearing masks are allowed inside a premises. The normal flu is the main symptom of this sickness. Hence, the best preventive measure for this disease is a face mask covering both the mouth and nose. In crowded public venues like hospitals and marketplaces, it is recommended by both the government and the WHO that individuals must cover their faces with face masks. Addagarla et al. [14] offered an original approach for detecting face masks by cascading 3 CNN techniques: YOLO V3, Facenet, and Mobilenet. It uses a 2ndCNNmethod known as Facenet to identify faces, which are then passed on to Mobilenet so that masks may be identified. In the approach that has been suggested, the detection of masks is treated as a binary class issue in which people with face masks and those who do not wear masks are differentiated from one another. The YOLO V3 and Facenet designs have implemented a transfer learning strategy.

Islam et al. [15] described the use of Python, OpenCV, TensorFlow, and Keras to develop this face mask detector, which was then trained using data. Before entering a building, everyone should ensure they always have a mask with them.

Someone discovered without a face mask will cause an alarm with a beeping sound. As a direct consequence, every place of employment reopened, and the sum of COVID-19 cases recorded across the world shot up. It is possible to put an end to this provided everyone follows the safety procedures. Because of this, it is anticipated that our study will make it easier to identify employees who come to work wearing masks. Siegfried [16] suggested a project that slows the spread of COVID-19 by monitoring whether someone is wearing a facial mask and checking their temperature. The person's body temperature is tracked via a non-contact Infrared temperature sensor. The method will be reinforced by being trained on a range of scenarios to prevent false positives. The technology takes a person's body temperature after spotting a mask. Militante et al. [17] identified the face masks in videos; this project used deep learning. There are two elements in the suggested framework. The second part of the system processes these facial frames into the proposed deep transfer models MobileNetV2 to identify the mask area. The first section uses OpenCV and machine learning to detect and recognize faces. The suggested structure was evaluated using various film and smartphone camera photographs. Finally, Williams [18] presented a comprehensive analysis of the fundamental prerequisites for such a model. Much discussion has been had regarding the requirement and the suggested model's architectural framework. This was accompanied by an in-depth study of the many different methods that are now accessible and a comparison of their performance levels. It would be tedious and time-consuming to individually examine each person's face in a public setting to describe whether or not they are donning a face mask. Building an automated process was necessary since there was an urgent need to monitor people wearing face masks. At the moment, separate approaches that use ML and DL can be utilized successfully.

2 Methodologies

People must wear the face mask per the suggested technique's rules, facilitating real-time input processing. The subsequent sections of this article detail the system's processes for identifying whether or not a person is wearing a mask. To determine if someone should wear a mask, a model first has to be trained using the required dataset. For identifying the wearing or not wearing of a mask, we recommend using our technique ABGAN-MOIHBMO. This effort intends to increase the accuracy of mask detection without substantially raising the resource requirements. Figure 1 is a flow diagram depicting the methodology used to develop this study.

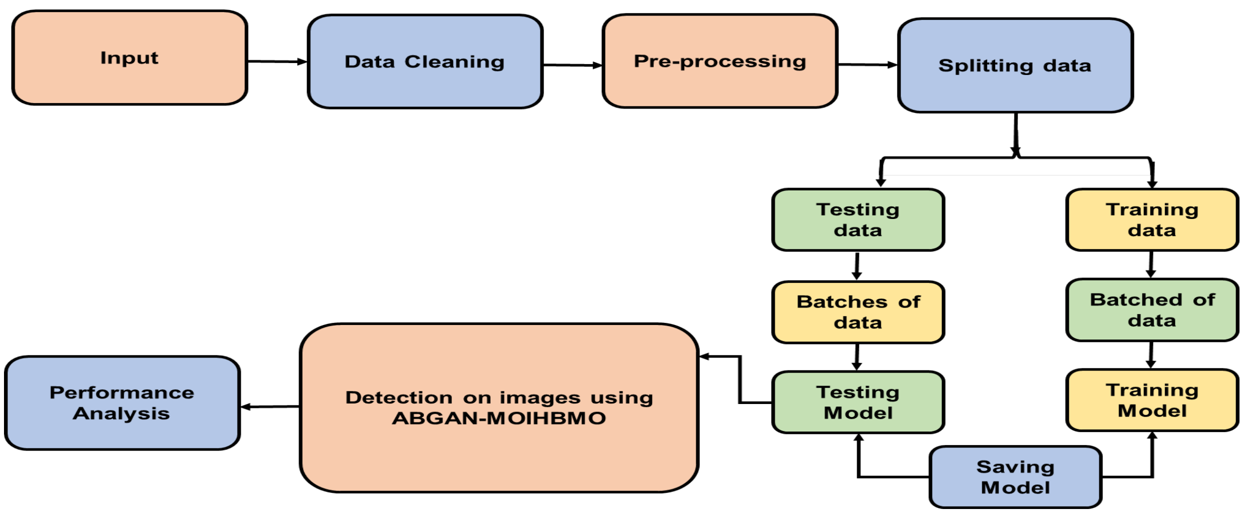

Fig. 1: Flow of our proposed methodology

Step1: Data visualization

Data visualization is the first step, and our training dataset comprises several images. We started by showing the ones which fit into the main category. The database contains 686 pictures of people wearing face masks, classified as "yes," and 690 pictures of persons without face masks that have been flagged as "no."

Step 2: Data Augmentation

Data augmentation is the second stage. As we proceeded through this process, additional photographs were included in the Dataset for data augmentation, and each image was inverted. We had 1376 photos, of which 686 were classified as "yes" and 690 as "no," utilizing the data augmentation technique.

Step 3: Dividing the data

We divide the Dataset in the third step into two groups: 20% provide validation data for the suggested method, while 80% serve as training. A series of photos with facial masks for training purposes six hundred eighty-six images with face masks are included in the training dataset.

a. Preprocessing

This process comprises compilation of data from the images in this dataset for masked face identification and uses a lot of repetitions and noise. As a decent dataset determines how accurate a model would be after being trained on it, the data from the aforementioned datasets were used. Once a duplicate had been analyzed, each of these was manually removed. Data cleaning was intended to eliminate the flawed images found in the Dataset, as mentioned earlier, manually. Discovering these images was an important step. As is widely known, dealing with corrupt photographs can be challenging, but with the help of sincere efforts, we carried out this task and cleaned the dataset using mask-donning images and those without. Any prediction model is adversely affected until inaccuracies in the Dataset are cleaned, identified, and fixed. Hence the justification of this step.

b. Attention-Based Generative Adversarial Network (ABGAN)

AB-GAN comprises the AB-GAN module and the RL module, which adjust the GAN hyperparameters. An outline of the AB-operation GANs is provided below:

- The GAN modules with the prior traffic flow concurrently.
- To gain the capacity to forecast, train the GAN modules using CNN and the self-attention method.
- Adjusting the RL module's GAN variables makes the GAN modules stable.

The generator and the discriminator are the components of a GAN module. Instead of using RNNs in the generator, we recorded the time-series data patterns using the attention layer. The discriminator employed CNN to pinpoint the traits of generated and projected information. The generator provides the desired time-series data from the historical data input. Rather than using RNNs, the attention layer collects the input data patterns. Additionally, parallel processing can speed things up. Following the attention layer, the feed-forward layer is the one that generates the prediction results.

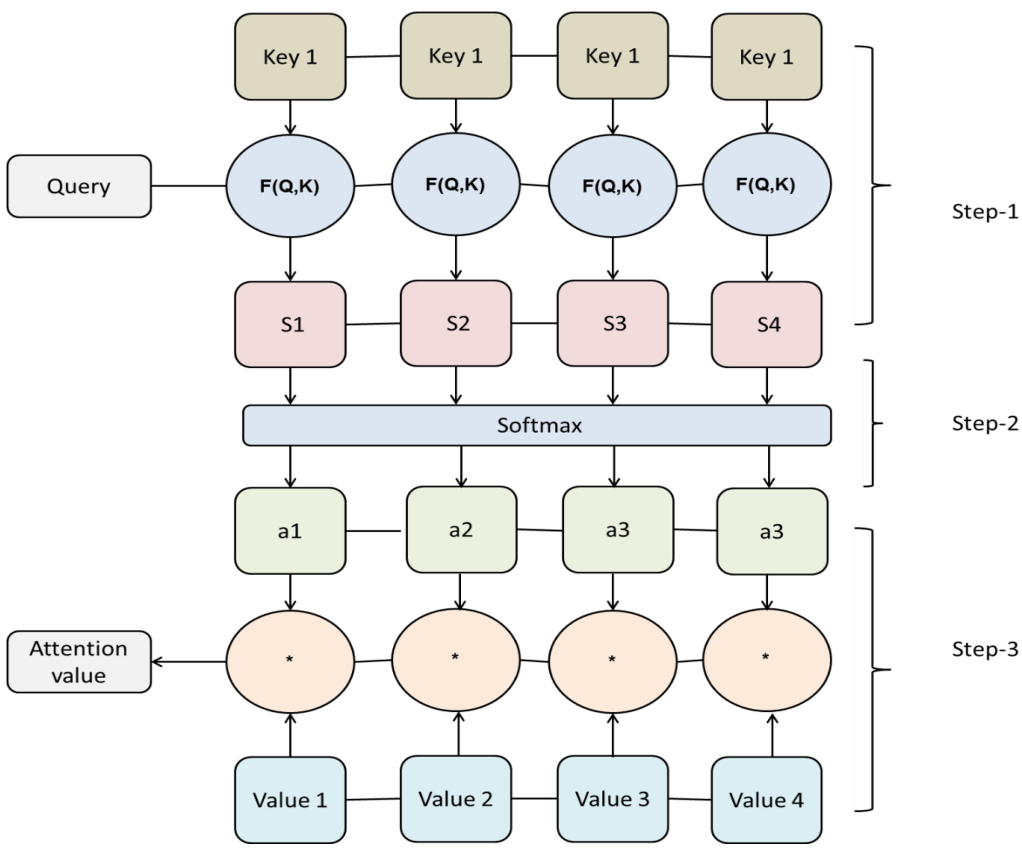

Fig. 2: ABGAN computation process

Figure 2 represents the ABGAN computation process. Theoretically, attention replicates people's experience by selectively excluding most of the least important information and concentrating on the critical data while disregarding the majority. The weight coefficient of data is calculated as the significant step in the attention data selection procedure. The self-attention system determines its attention weight. Initially, we calculated the input embedding from W_j traffic flow data and data location to make the Query, Key, and Value embedding.

Query $= X^r . Y_j$, Key$= X^l . Y_j$, Value$= X^u . Y_j$ (1)

There are three steps in the self-attention technique.

Determine how identical or correlated the two are based on the Query and Key.

$\text{Sim}(\text{Query}, Key_j) = \text{Query}, Key_j$ (2)

Normalize the outcome of the first step's calculation to derive a weight coefficient utilizing softmax;

$b_i = \text{Softmax}\ (Sim_i)$ (3)

A weighted addition of Value makes up the weighting coefficient.

Attention (Query,Source) $= \sum_{j=1}^{K_w} b_{j.} Value_j$ (4)

The discriminator's inputs are divided into actual data and prediction data, and its outcomes include classifications like whether the prediction data was accurate or not, as well as the generator's and discriminator's confidence values. One of the agent's primary qualities is the capacity to communicate with its surroundings for computational analysis and decision-making. A person or thing called an agent can act in response to its surroundings.

The AB-GAN approach utilizes an RL technique to optimize the generator (G) and discriminator's hyperparameters and train the attention-based GAN models (D). When dealing with various datasets, the generator (G) and discriminator (D) hyperparameters must be adjusted because they impact traffic flow prediction performance. In addition, the hyperparameters are tuned using an RL learner. The training of the GAN and RL systems is done concurrently with the input of the data on traffic flow and initialization of the hyperparameters for the G and D. Thereafter we set the hyperparameters for the G, trained the GAN models, and then used the RL framework to tweak the hyperparameters for the D until RL discovered the best hyperparameters. The hyperparameters for the D are specified, GAN models trained, then the RL approach used to manipulate the hyperparameters for the G until the RL model discovered the ideal hyperparameters. These directions are followed again; the RL model assists the G and D find their ideal hyperparameters.

c. Multi Objective Interactive Honeybee Mating Optimization (MOIHBMO)

The versatile and well-balanced mechanisms of the basic MOIHBMO method help improve local and global exploration capabilities. The fundamental drawback of the MOIHBMO method is its potential to miss the optimum, its inability to increase exploitation capability, and its short timeframe for providing a solution close to the optimum. Nonetheless, the conventional MOIHBMO technique successfully identifies the optimum solution to an optimization problem. In other words, the initial breeding process of the drone bee's movement solely considers the relationship between the honeybee, chosen by the mating wheel selections, and the one being selected randomly. Thus, it needs to be more robust to maximize the ability for exploitation. The MIHBMO method is presented based on the structure of the actual HBMO technique to address this shortcoming.

When the first and second particles' masses ($m_1 and m_2$) and their separation r_{12} are taken into account, the gravitational force among the two particles F_{12} can be written as follows:

$$F_{12} = G\frac{m_1 m_2}{r_{21}^2}\widehat{r_{21}} \quad (5)$$

Here, G is the gravitational constant. r_{21} represents the unit vector in Eq. (6):

$$\widehat{r_{21}} = \frac{r_2 - r_1}{|r_2 - r_1|} \quad (6)$$

In other terms, each dimension's gravitational intensity is independently determined. As a result, the Eq. (7) can be used to describe the gravity on the *j*th measurement among parent and parent. Lastly, Eq. (8) may be employed to change Eq. (5) during the iteration interval t:

$$F_{ik_j} = G\frac{F(parent_i)\times F(parent_k) parent_{kj} - parent_{ij}}{(parent_{kj} - parent_{ij})^2 |parent_{kj} - parent_{ij}|} \quad (7)$$

$$child_{ij}(t+1) = parent_{ij}(t) + F_{ik_j}.[parent_{ij}(t) - parent_{kj}(t)] \quad (8)$$

By including additional drone bees and more than one drone bee, the universal gravitation between the drone bees that the queen bee chooses can be extended. It is possible to eliminate the G by normalization. An agent is a thing that can do things based on how it perceives and observes the world around it.

The feed-forward layer is the one that generates the prediction results.

3 Results and Discussion

Persons without masks can be recognized and alerted using installed IP cameras or legacy devices that have been expanded to the networks. Users can also put their phone numbers and faces to their expandable networks so they can be contacted when without a mask. If administrators think a user has been correctly detected in the camera, consumers might receive messages.

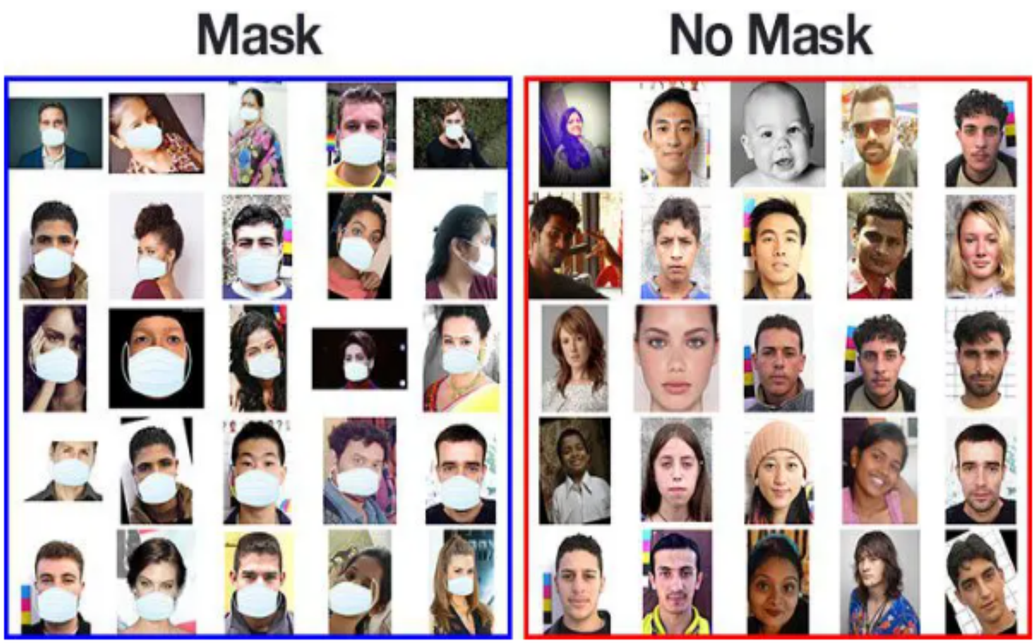

Fig. 3: Example of Dataset

Figure 3 shows the Dataset provided for the execution. There are 1386 images from Saudi Arabia in the training dataset and 278 in the evaluation dataset. Mandatory mask-wearing is the predetermined requirement for public transportation during this epidemic. Our database system was built using pictures of people wearing, not wearing, and partially wearing masks. Images with a mask on them but not covering their noses are seen as having no cases. This implementation aims to detect ethical face mask donning with 100% accuracy [19].

The suggested face mask detection system's efficacy is assessed and contrasted with that of other current techniques in terms of recall, precision, accuracy rate, and error rate, f1 score. In this section, we have compared our model with other traditional methods like deep neural network (DNN [20]), Artificial intelligence (AI [21]), and Deep Learning (DL [22]), and our suggested technique is an attention-based generative adversarial network with the multiobjective interactive honeybee mating optimization (ABGAN-MOIHBMO). Here, we discuss the outcomes of the facemask detection system in detail.

Accuracy is the level to which the measurement outcome corresponds to the right value or standard. Still, it relates to how closely a measurement resembles the previously agreed-upon value in practice. The degree to which a measurement corresponds to its actual value is referred to as its accuracy. The accuracy can be calculated by using the expression:

$$Accuracy = \frac{TN+TP}{TP+FP+TN+FN} \quad (9)$$

Here, TN denotes the true negative, TP represents the true positive, FP denotes the false positive, TN means the true negative, and FN denotes the false negative.

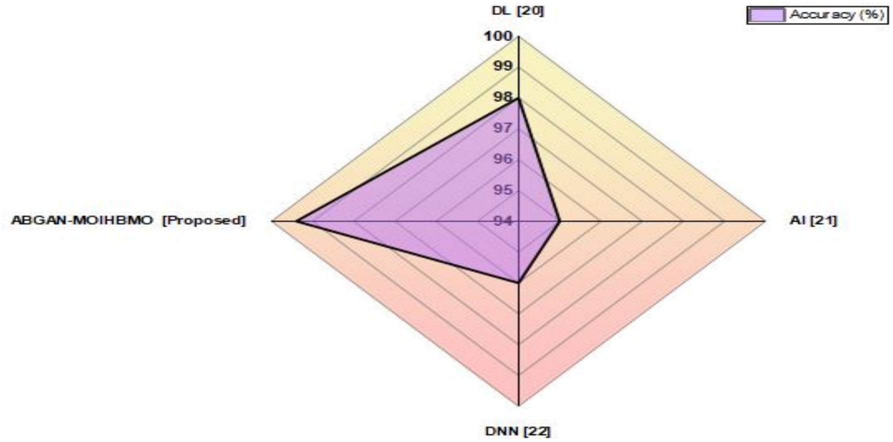

Fig. 4: Comparison of accuracy with traditional and suggested technique

Table 1: Performance of accuracy

Methods	Accuracy (%)
DL [23]	98
AI [24]	95
DNN [25]	96
ABGAN-MOIHBMO [Proposed]	99.4

Figure 3 represents the accuracy of our model compared with traditional and suggested techniques, and Table 1 illustrates the accuracy performance. Compared to other conventional methods, our suggested ABGAN-MOIHBMO provides 99.4 percent of accuracy detection, which is higher than other methods.

The proportion of cases in which an accurate face mask recognition was made relative to the overall number of instances in which identification was made. Precision evaluates the proportion of instances or samples correctly classified between those determined to be positive. The following is the formula that can be used to measure the precision:

$$Precision = \frac{TP}{(TP+FP)} \quad (10)$$

Here, TP signifies the true positive rate, and FP illustrates the false positive.

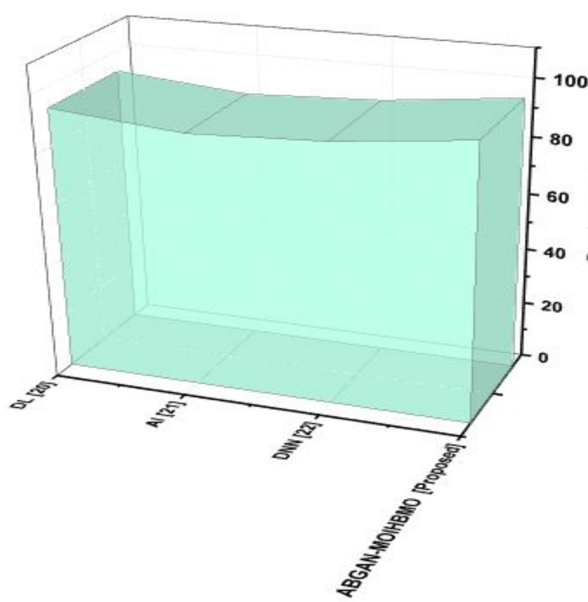

Fig. 5: Comparison of Precision with traditional and suggested technique

Table 2: Performance of precision with traditional and suggested technique

Methods	Precision (%)
DL [26]	93
AI [27]	89
DNN [28]	91
ABGAN-MOIHBMO [Proposed]	96

Figure 5 compares the precision of our model with traditional and suggested techniques, and Table 2 represents the accuracy performance. Compared to other conventional methods, our suggested ABGAN-MOIHBMO provides 96 percent of precision, which is better than other methods.

The proportion of expected counts of face masks discovered relative to the average number of face mask images that are relevant. The method effectiveness depends on the recall score, which considers how accurately the process counts the number of true positives relative to the total number of positive values. Regarding information retrieval, the term "recall" denotes the proportion of pertinent documents that were successfully located. The recall can be measured using the expression:

$$Recall = \frac{TP}{TP+FN} \quad (11)$$

Here, TP signifies the true positive, and FN signifies the false negative.

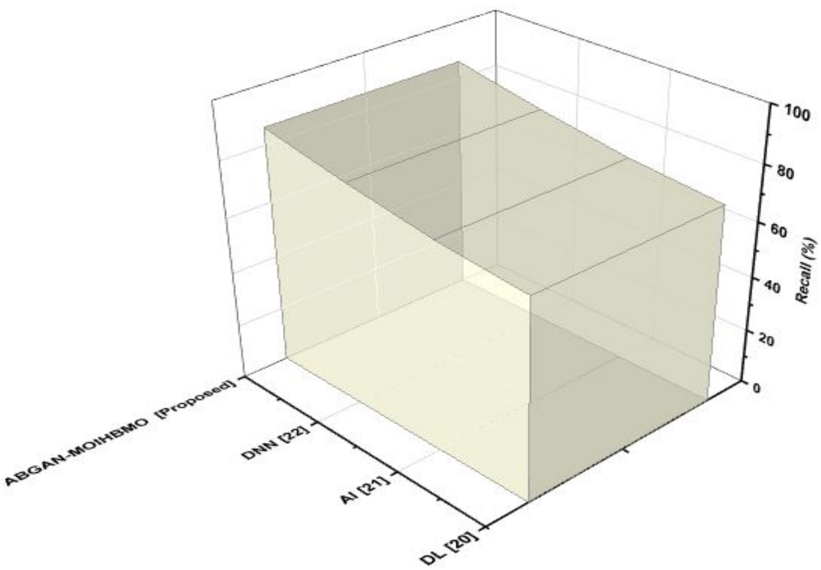

Fig. 6: Comparison of recall with traditional and suggested technique

Table 3: Performance of recall

Methods	Recall (%)
DL [29]	72
AI [30]	75
DNN [31]	80
ABGAN-MOIHBMO [Proposed]	86

Figure 6 represents the recall comparison with traditional and our suggested techniques, and Table 3 denotes the recall performance. Compared to other conventional methods, our proposed ABGAN-MOIHBMO method provides 86 percent of recall, which is higher than other methods.

The F1 score is determined using the harmonic mean of recall and precision. Remember that the harmonic mean may be utilized in place of the more popular arithmetic average. When calculating an overall average, it is frequently helpful. The F1-score is frequently utilized in conjunction with other measures, including the mean average or the 11-point interpolation mean precision, to obtain an accurate picture of the searched engine's overall performance. The F1-score can be determined by using the following expression:

$$F1\ score = 2 \times \frac{precision \times recall}{precision+recall} \quad (12)$$

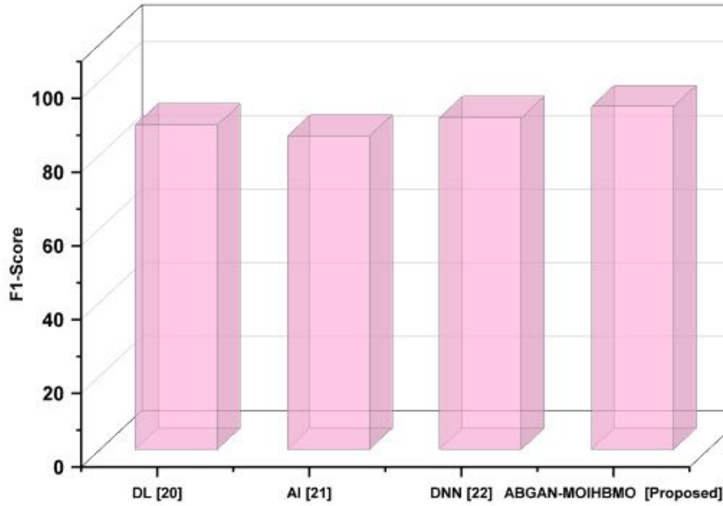

Fig. 7: Comparison of f1 score with traditional and suggested technique

Table 4: Performance of f1 score

Methods	F1-Score
DL [32]	88
AI [33]	85
DNN [34]	90
ABGAN-MOIHBMO [Proposed]	93

Figure 7 represents the comparison of the f1 score with traditional and suggested techniques, and Table 4 denotes the efficiency of f1score**.** Compared to the other conventional techniques, our proposed ABGAN-MOIHBMO technique provides 93 percent for the f1 score, which is better than traditional techniques.

By comparing the input data from the transmitter and receiver, the Error Rate Calculation block determines the error rate. The block splits the total number of uneven pairs of data items by the overall number of input data pieces from a single source to determine the error rate. This inaccuracy frequently occurs when one of the most strongly predicted classes doesn't match the actual class. An error rate is calculated using the formula below:

$$ER = \frac{TW}{TE} \tag{13}$$

Here, TW denoted the average set of wearing mask, and TE indicated the total set of errors.

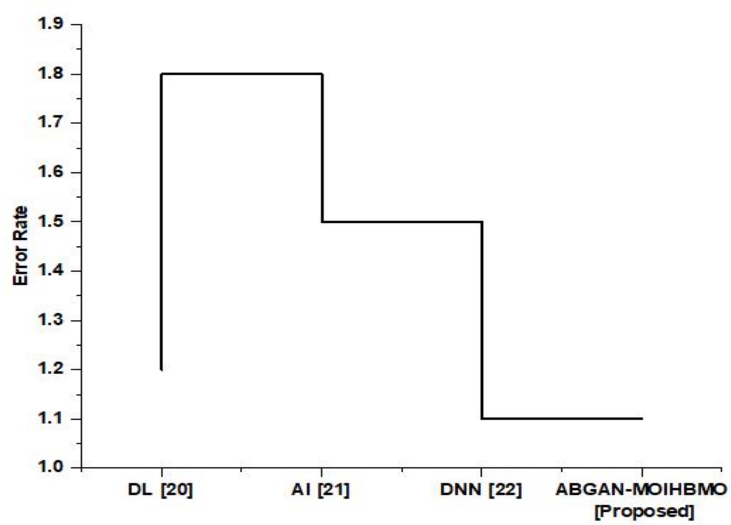

Fig. 8: Comparison of error rate with the traditional and suggested technique

Table 5: Performance of error rate

Methods	Error Rate
DL [35]	1.2
AI [36]	1.8
DNN [37]	1.5
ABGAN-MOIHBMO [Proposed]	1.1

Figure 8 denotes the error rate compared with traditional and our suggested techniques, and table 5 represents the error rate performance. Compared to other conventional methods, our proposed ABGAN-MOIHBMO technique provides a 1.1 percent of error rate, which is lower than different approaches.

Keeping a close eye on the model's precision and accuracy throughout the testing and training stages, consisting of 20 epochs, is essential. In addition, as seen in Figure 8, the accuracy techniques improve over time and become stable after Epoch=2.

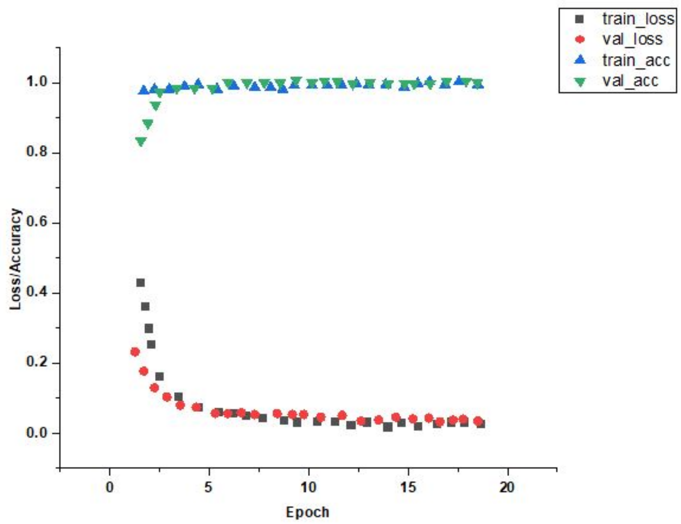

Fig. 9: Training vs. Evaluation

4 Conclusions

The recent virus outbreak named COVID-19 has made people aware of the advantages of wearing face masks. Face masks must be worn when riding public transport and may need to be enforced at times. This work used ABGAN-MOIHBMO to create a face mask detection system. A set of 1386 images has been used to create a real-time dataset. This database contains 690 pictures without a face mask and 686 images with it. The suggested algorithm ABGAN-MOIHBMO was compared to other traditional methods for detection of face mask, such as DL, AI, and DNN. The performance indicators used are error rate, inference speed, precision, recall, accuracy, and over fitting assessments. The results demonstrate that the proposed approach has outperformed the existing methodologies, with an accuracy of over 99% and an error rate of less than 2%. To predict and underline the significance of face mask use, the face mask detection technique may be employed in the future at airports, shopping centers, and other congested locations.

5 Recommendations

It is recommended that ABGAN-MOIHBMO algorithm should be applied at the Saudi Arabia face mask detection market study analyzes the Saudi Arabia market's competition and consumer behavior. In future, it is recommended that further studies investigate in-depth the insights provided by the application ABGAN-MOIHBMO algorithm at various Saudi locations. It is further recommended that the model be tested for detections of other nature to establish its perfection in the required domain. Also, review studies and big data analytics may be used to test the model with even larger datasets.

Conflicts of Interest Statement

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter *or materials discussed in this manuscript.*

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