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Developing an Automated Vision System for Maintaing Social Distancing to Cure the Pandemic

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Abstract

The world is currently facing a medical crisis. The epidemic has affected millions of people around the world since its appearance. This situation needs an urgent solution. Most countries have used different solutions to stop the spread of the epidemic. The World Health Organization has imposed some rules that people should adhere. The rules are such, wearing masks, quarantining infected people and social distancing. Social distancing is one of the most important solutions that have given good results to confront the emerging virus. Several systems have been developed that use artificial intelligence and deep learning to track social distancing. In this study, a system based on deep learning has been proposed. The system includes monitoring and detecting people besides measuring the social distance between them. The proposed system consists of two parts: (1) detecting the faces of people using the Viola-Jones algorithm. The Cascade classifiers were trained. The Cascade classifiers used in the algorithm with feature descriptors to detect side faces and wear masks. Hence, training is dominant for detection. (2) measurement of the Euclidean distance between the centers of the rectangles of the people who were revealed in the first part. The distance between individuals' is measured to check how well they adhere to social distancing. The results revealed that the proposed system can perform well in applying images to track the distance between people.

Keywords: *Face Detection , Social Distancing, Viola-Jones.*

1. Introduction

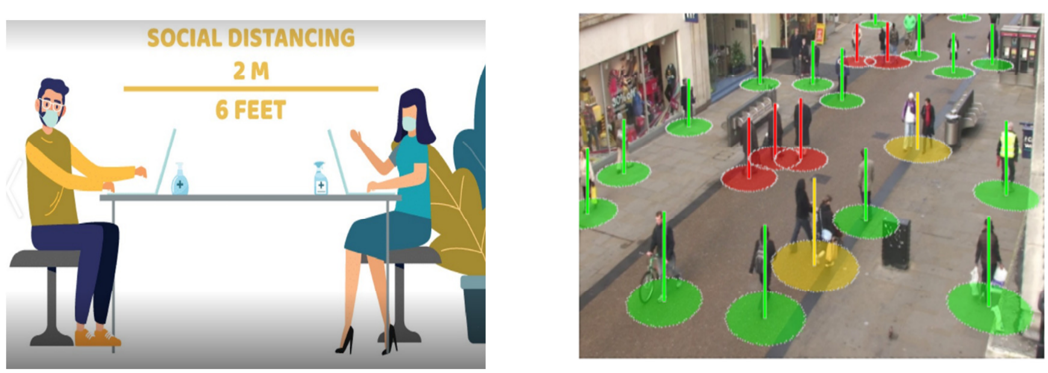
Deep learning represents a renewed and developing field of research that deals with finding theories and algorithms that allow the machine to learn on its own by simulating the work of neurons in the human brain, so it is part of machine learning. Most researchers in the field of deep learning focus on finding new algorithms and developing old ones by analyzing a huge data set [1].

Deep learning has made wide, rapid and effective progress in many areas, including face detection and recognition, speech recognition, and computer vision. The machine is taught from big data using various designs of deep learning networks such as recurrent networks (RNNs) and convolutional neural networks (CNNs). An image can be described on the basis of the degree of brightness in each pixel and expressed as a vector or by expression based on the sum of the edges and regions that make up the image[2]. One of the goals of deep learning is to replace human-defined features of machine learning with features that are extracted by efficient feature-extracting algorithms and are produced by the machine itself[3]. Due to the development in deep learning and its use in various aspects of life, researchers have tended to exploit computer vision and image processing. Computer vision and image processing are the processes of converting images into digital information and changing the nature of images to make them more convenient and simpler to understand by the machine and also improving the graphic information and its interpretation of the human being[4]. That is in, observing the social distancing between people and the extent of their commitment to it.

Considering the spread of epidemics and diseases, scientists and researchers are trying to find appropriate solutions to stop the spread of these diseases. They found that social distancing is one of these important solutions that prove its effectiveness in reducing the spread of epidemics every time it is used. The main purpose of social distancing and imposing a safe distance between people must be adhered to with the various ways in which it is implemented[5].

A distance of 2 m has been determined as a safe distance in most countries, and this has been determined by governments and health authorities, and it is considered a mandatory measure at the time of epidemics [6]. The other form of social distancing is imposing a ban and keeping people in their homes, as well as quarantining the injured [7].

In this paper, a system based on deep learning is proposed to automatically detect people's faces and monitor the social distance. In the article, the first part of the proposed system was clarified, which is Face Detection, and its algorithm. The Viola-Jones algorithm, is one of the deep learning algorithms. The algorithm was used with training using one of the feature descriptors to improve classification performance. Second, the distance between the people who were discovered was measured to determine their commitment to social distancing. The model showed good performance through the experimental results.



A **B**

Fig. 1. A. Social distance must be between people [8]. B. Monitor social distancing [6].

2. Related Work

In this part, some of the previous systems that were proposed to monitor social distancing are briefly presented. The systems measure the distance between people, and alert violators of the safe distance. With the spread of epidemics, researchers began to work to find solutions that control the spread of the epidemic widely around the world. Social distancing has been suggested as one of the important solutions in such circumstances, which proves its effectiveness every time it is used. Economically speaking, social distancing is a strict measure to flatten the curve against diseases infectious. Many countries have turned into this technology to be exploited in monitoring and implementing social distancing. Detecting objects largely contributes to such a situation. Many researchers have studied the situation to discover different types of objects that help in the scenario [9-12]. A well-established field of research is human discovery. Recent developments in this field have contributed to a greater demand for intelligent systems to monitor extraordinary human activities [13, 14]. Despite the difficulties faced by human detection such as blurred video clips, various articulated poses, background complexities and limited machine learning capabilities, it is an interesting area, and the detection performance can be enhanced by existing knowledge [9]. Narinder et.al. proposed a system based on deep learning to automatically monitor the distance between people using video surveillance [10,11]. People were separated from the background using YOLO V3 algorithm [15] with deep sorting technology, and with the assistance of surrounding boxes, the detected people are tracked.

Adina Rahim et. al. [16] have proposed a system for monitoring social distancing in low-light environments and at night. It is based on YOLO v4 training [17] on the ExDarknet dataset to monitor social distancing with the use of a raft camera. The camera is fixed to monitor people at the distance installed by the camera and the resulting distance is shown in real world units.

As for the scientist Shashi Yadav[18] he proposed a system based on computer vision to detect people in real time through automatic monitoring in public places. The researcher implemented his proposed system on Raspberry Pi 4 to monitor the activity and detect if there is an overdose through the camera. Engineering techniques and deep learning algorithms have been combined to build a powerful system that detects, tracks, and checks, as it sends an alert if the distance is violated.

In another proposal, researchers Mahdi Rezaei and Mohasen Azarmi [6] presented a system that uses CCTV surveillance cameras with the development of a deep neural network to automatically detect people and calculate the distance between them in crowded places. The human detector was used DeepSocial and this system was developed to be able to work in different conditions such as changing lighting, obstruction, shadows and partial vision.

Afiq Harith et. al. [19] introduced a system that monitors the social distance between individuals and detects people using the SSD[20] object tracking system, as well as the OpenCV[21] library for image processing. Installed pixel values are chosen and after calculating the distance between people, they are compared with these installed values to see if this distance has been exceeded or not.

Krisha and others [22] suggested another system that helps in detecting social distancing between people and detecting violations. The system uses a deep learning algorithm YOLO v4 to detect people, after identifying them , the distance between them is measured using the coordinates through the principles of optics.

As for Yew Cheong Hou et. al.[23] they proposed a system that uses the YOLO v3 deep learning algorithm, through which people are detected using the open source to detect pre-trained objects. As for the distance between people, it is calculated from the 2D plane by converting the video frame into a top-to-bottom view. After estimating the distance between them, a red frame is placed around the people who do not comply with the permissible distance.

Several research studies have been conducted to monitor social distancing and provide the best effective solution for social distance monitoring. That is by using multiple algorithms of deep learning algorithms and integrating them with other methods as discussed previously. In this study, one of the deep learning algorithms " Viola-Jones algorithm" was used to detect and identify people so that the social distance between them is monitored. This algorithm has not been mentioned before in monitoring social distance between people. Therefore, this work focuses on the use of the Viola-Jones method to monitor the distance between people and how it has been trained to detect faces in different situations.

3. Background of Deep Learning Models

In the process of monitoring the distance between people, the presence of these individuals in the photo or video clip is first detected. This is done through machine learning, which is represented by deep learning algorithms with computer vision or image processing. One of these algorithms are R-CNN and its version (R-CNN[24] , Fast R-CNN [25], Faster R-CNN [26]). The working principle of R-CNN is to suggest the area, which is represented by the surrounding boxes [16]. The sliding window method was utilized by the classifier and it is taken by taking a slice of the image, therefor, this is the principle of the oldest algorithm from R-CNN, which is the deformable fragments algorithm (DPM) [27].As for the newer algorithm currently, it is YOLO algorithm, which was proposed in 2016 by Joseph and others [28] and it detects objects in real time, and its other version is worked by the same principle. These versions are YOLO v2[29], YOLO v3[15] and in 2020 YOLO v4 proposal [17]. The general structure of the detectors for organisms consists of 3 parts: the spine, the neck and the last part is the head [17], as shown in Fig. 2. As for the main tasks of the detectors , they are represented by three tasks, which are:

1. Extracting traits
2. Choosing important traits
3. Classify the goals and enclose the desired goal in a square.

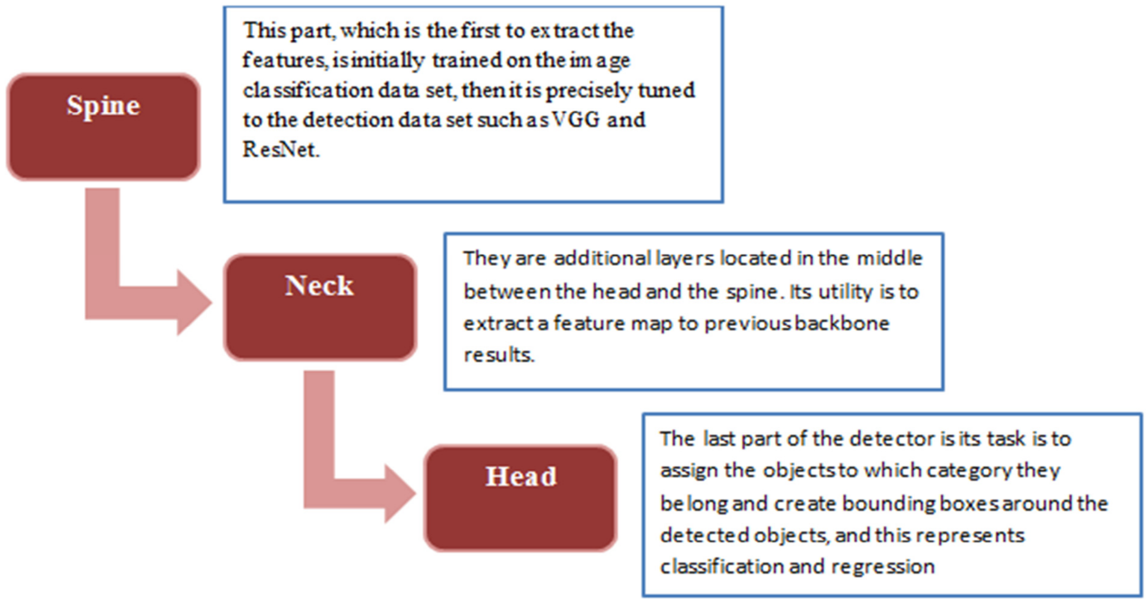


Fig. 2. General architecture of object detectors.

4. Methodology

This research aims to propose a system for measuring the level of threat or risk in public areas by monitoring social distancing between people. The proposed system is based on deep learning, where the presence of people in a particular area is first detected.

Second, the system measures the distance between the discovered individuals to determine whether they respect and apply the rule of social distancing.

To carry out the training process, we collected data that encompass faces and others that do not incorporate faces. Pictures that encompass faces are front and side, as well as some that wear masks. As for the pictures that do not contain faces used in training, the number is approximately double the number of pictures containing faces.

The system design consists of two parts that correctly handle the input images. The first part is face detection. The Viola-Jones algorithm was used to detect faces in the captured images and was trained to detect side faces as well. The second part measures the distance between the people discovered in the first part. Where the Euclidean distance between them is measured and compared with the proven distance to determine whether there is a violation of the safe distance or not.

The flowchart in Fig. 3 illustrates the flow of the proposed system.

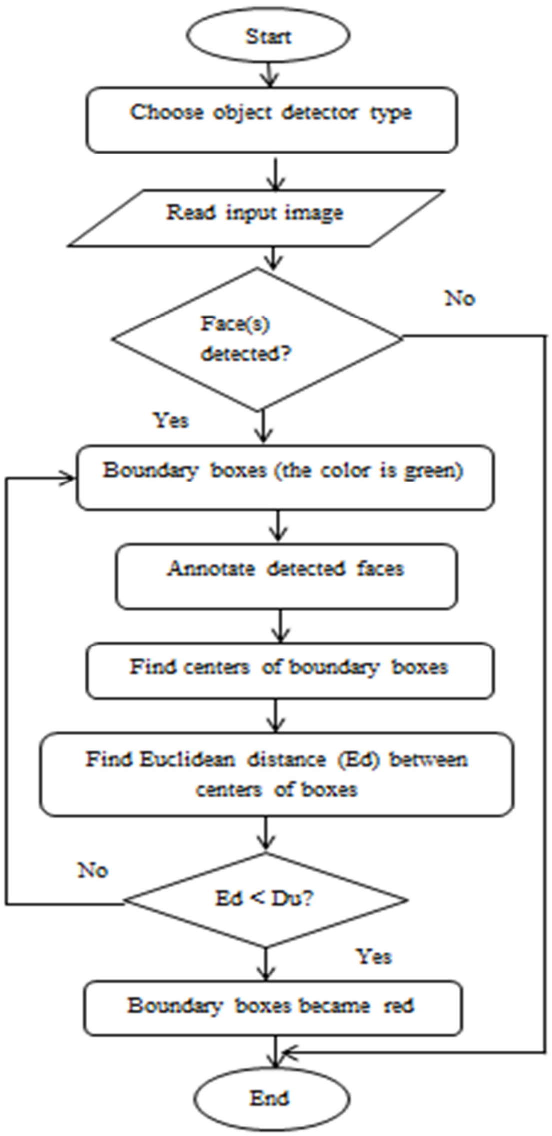


Fig. 3. Flowchart of the system.

4.1. Face Detection

Face detection is an essential part of the designed system. This stage is the first stage in the system before measuring the distance. In this part we need an effective detector that can detect masked faces. Furthermore, that we need to localize complex cases such as side faces, hence, we relied on a deep learning algorithm that is pre-trained to detect faces. It was trained to detect side faces and mask wearers, this algorithm is Viola-Jones.

Viola- Jonse algorithm

In 2001 the Viola-Jones method was proposed by researchers Paul Viola and Michael Jones for target discovery. The main objective for which this method was proposed is to detect faces and it can be trained to detect different things. Despite the acceptable results for this method, it has some limitations. For instance the front face must be fully visible and erect, the face must be completely facing the camera and must not lean to either side[30]. The Viola-Jones method has three components that work collectively to be detected quickly and accurately, and these components are the integrated picture for feature calculation, Adaboost for feature selection and Cascade to effectively reduce computational resources. It also uses Haar-like features [31].

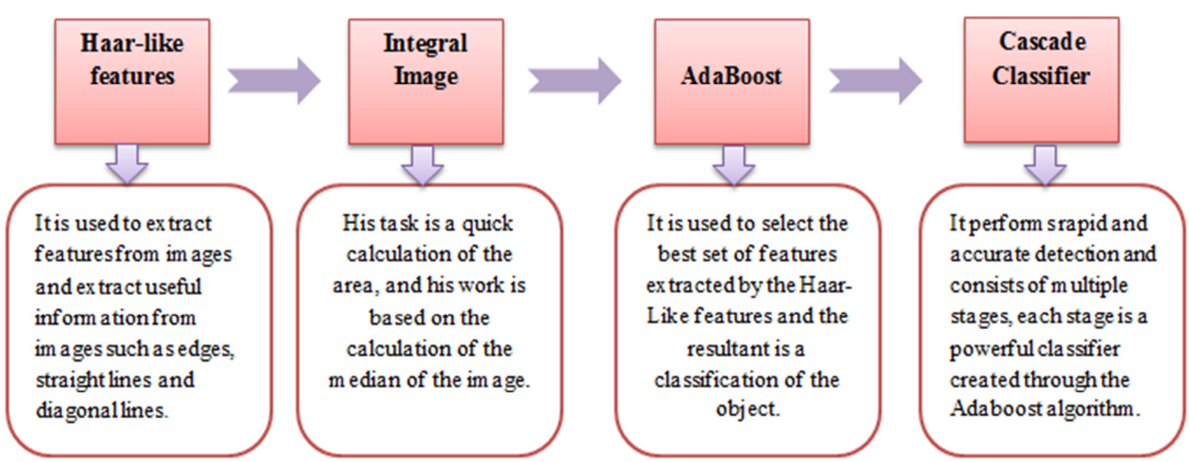


Fig. 4. General Architecture of Viola-Jones algorithm.

After the faces are detected, they are surrounded by rectangles, and these rectangles are changed in color according to the distance between them.

Fig. 5. Face detected by Viola-Jones.

4.2. Measure Social Distancing

Measuring the distance between people is the second part of the proposed system. This part depends on the first part of the system, where in the first part people are detected and their locations in the image are determined. The positions of the individuals in the picture are four coordinates for each perimeter: x, y, w and h. x and y represent the upper left corner of the bounding rectangle, while w and h represent the width and height of the bounding rectangle of the detected object.

These coordinates are used to check whether there is a violation of social distance or not by measuring the distance between the centers of the rectangles surrounding the detected face. The centers of the rectangles are calculated using equations 1 and 2. We assume that the central coordinates of the rectangle of the first face are x_{c1} and $y_{c1}$and that the coordinates of the center of the second face are x_{c2} and y_{c2}, and the Euclidean distance[29] between them is measured by equation 3.

$$\text{Xc}= x + \frac{w}{2} \quad \ldots(1)$$

$$\text{Yc}= y + \frac{h}{2} \quad \ldots(2)$$

$$\text{Ed} = \sqrt[2]{(x_{c2} - x_{c1})^2 + (y_{c2} - y_{c1})^2} \quad \ldots(3)$$

Next, the distance is compared with the experimentally measured threshold parameter to determine whether these two individuals violated social distance. A calibration factor is used to convert the Euclidean distance from a pixel unit to a real-world unit, which is a unit cm, as in Equation 4. After finding the value of the calibration factor through experiments, we multiply the found Euclidean distance by the calibration factor we obtained to standardize the units.

Calibration Factor =

$$\left. {expriment \atop distans\ in\ cm} \middle/ {expriment\ distance \atop in\ pixels} \right. \quad \ldots(4)$$

A red box is placed on the people if the Euclidean distance (Ed) between them is less than the established distance (Du), indicating a violation of the social distance between them. However if the Ed is greater than the Du, green boxes are placed to indicate that they are committed to social distancing.

5. Training Data

We trained 138 pictures containing faces and 238 pictures without faces. The pictures were taken through a fixed raft camera at a height of 165 cm and after 400 cm from the iPhone 12 Pro Max mobile, and all the pictures were taken in the laboratories of Al-Khwarizmi College of Engineering. Some of the pictures were taken of non-frontal faces, as well as of faces wearing masks and medical scenes. Through the experiments all faces were identified.

Different numbers of the Cascade stage were utilized during the training, where we used 5, 7 and 9, and for each stage we used 3 values for the

False Alarm Rate, which represents the false positive rate, and the values in training were 10%, 7.5% and 5%. In total, we have 9 files that have been trained and images have been tested.

6. Experimental Results and Discussion

We trained the Cascade classifiers used in the detection algorithm utilizing two types of feature descriptors, which are histograms of oriented gradient(HOG) and local binary pattern(LBP). That is to choose those that give more positive results and more accuracy. When comparing the results that we obtained from the experiments, we find that the descriptors of the histograms give greater accuracy in detecting faces as in the Fig.6, This result was obtained when using 9 stages of classification and the False Alarm rate of 5%.

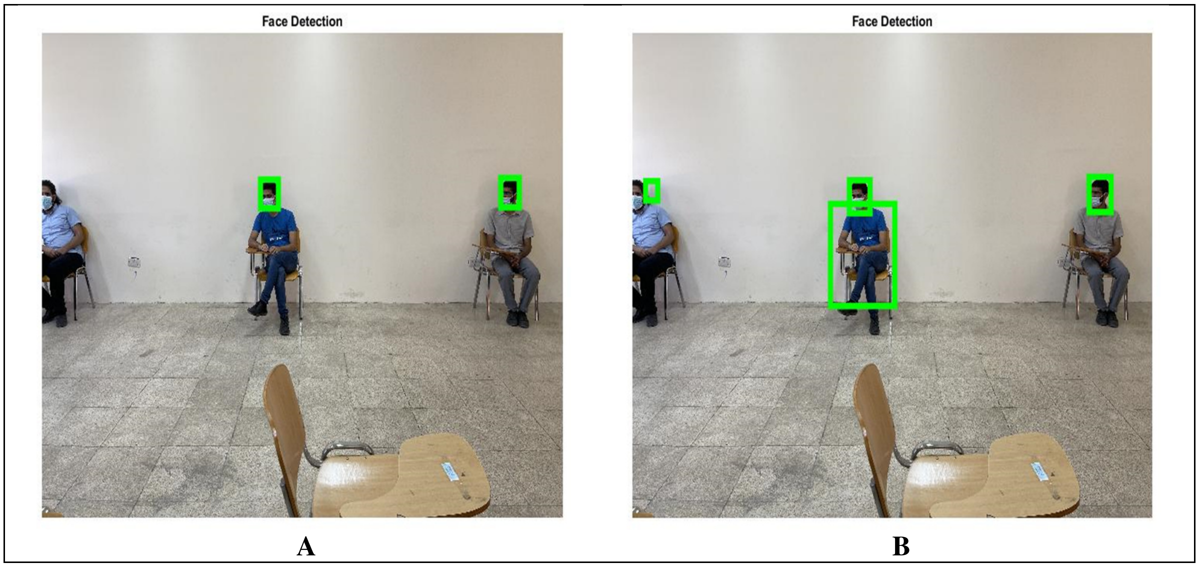


Fig. 6. Face detection A. Using HOG features. B. Using LBP features.

On the other hand, we tested the system on the faces wearing masks, we found that the Haar Cascade classifiers detected them after we did the training, also we are comparing the results got with what the researchers Muhanad Ramzi and Amar Idrees [32] mentioned that these classes cannot detect the faces wearing the masks and we use the same picture.

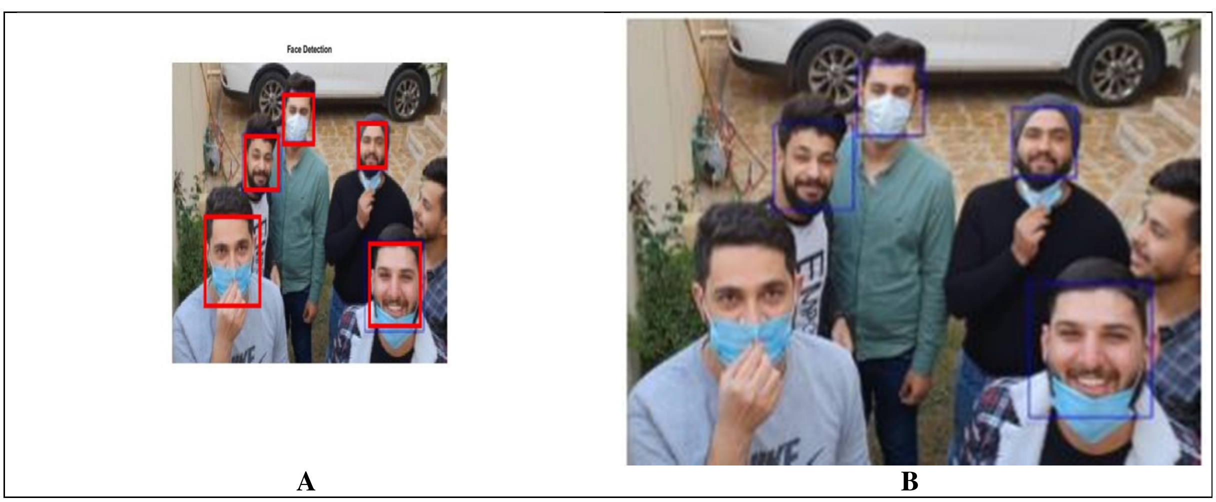


Fig. 7. Face detection with wearing masks A. Results from our system. B. Results from researchers [32].

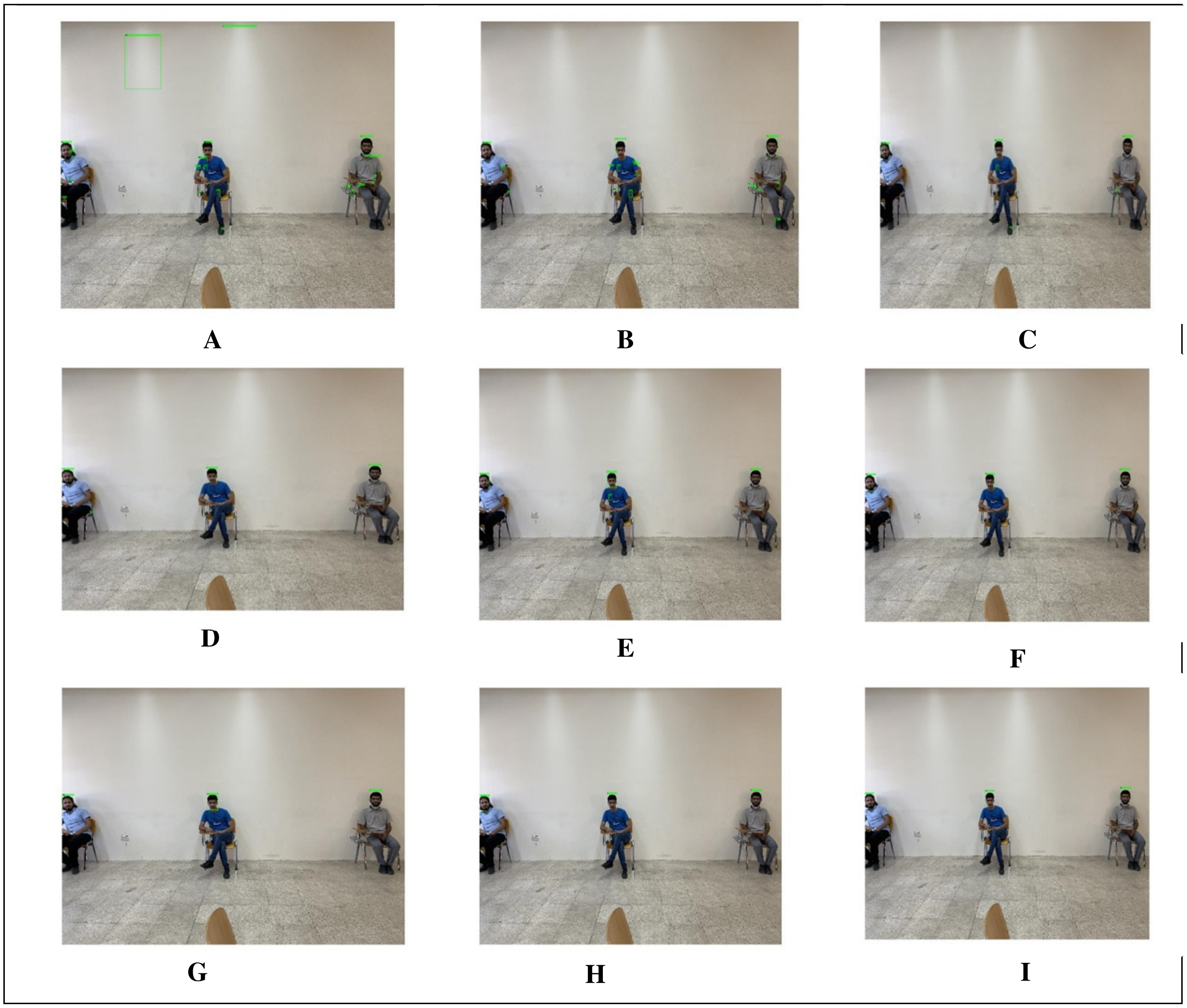


Fig. 8. Results through using different number of Cascaded Stage with different values of False Alarm Rate.

Table 1,
Number of Cascaded Stages & False Alarm Rate with their results.

No. of Cascaded Stage	False Alarm Rate	Results
5	10%	Fig.6. A
5	7.5%	Fig.6. B
5	5%	Fig.6. C
7	10%	Fig.6. D
7	7.5%	Fig.6. E
7	5%	Fig.6. F
9	10%	Fig.6. G
9	7.5%	Fig.6. H
9	5%	Fig.6. I

Through the experiments and the results, it became clear that the higher the number of stages and/or the lower the percentage of False Alarm Rate the more accurate the detection of faces and the lower the error rate, as shown in the Fig. 8.

The 9 training files were used to obtain different values of TP, which represents the positive results, FP the false positive results, TN true negative results, and finally, FN the false negative results. Figures 9 and 10 show these values and how they change by changing the number of Cascade stages and the False Alarm Rate values.

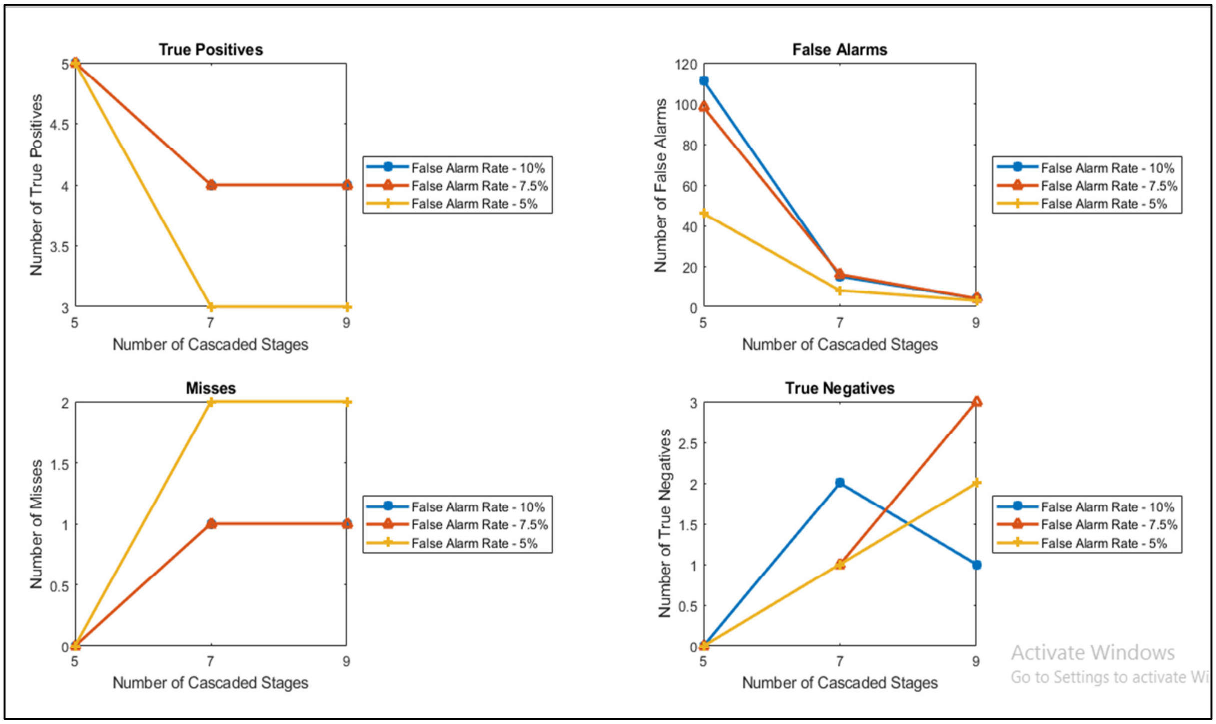


Fig. 9. Results with different Number of Cascaded Stage.

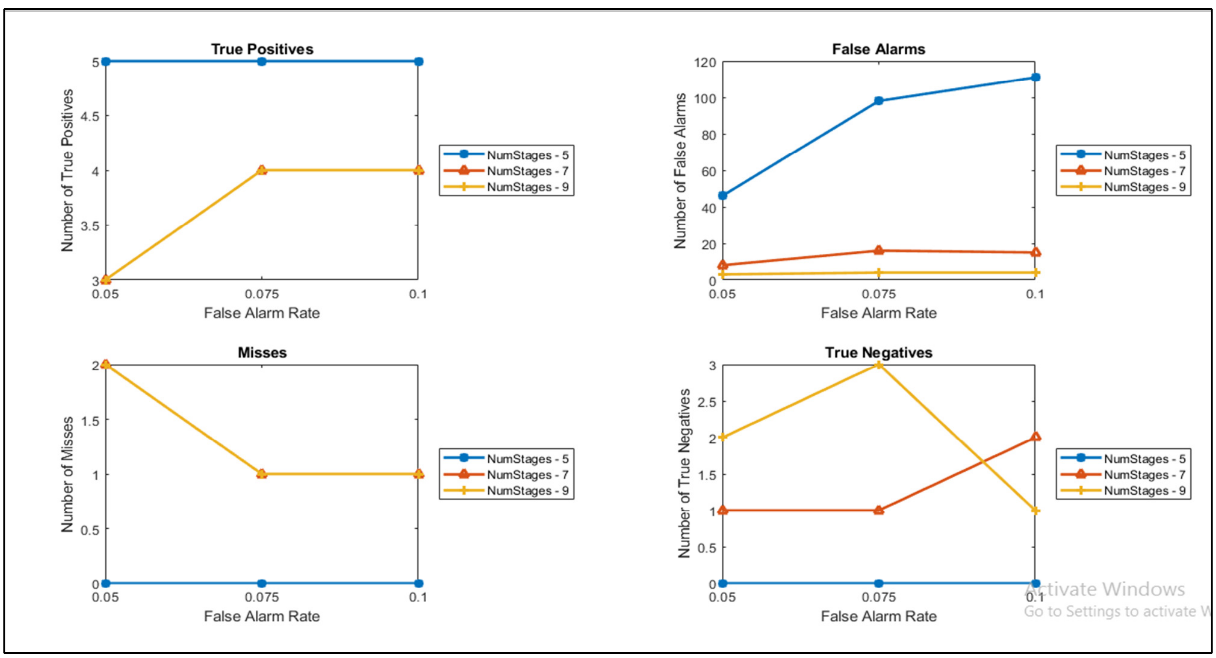


Fig. 10. Results with different values of the False Alarm Rate.

Another was done, that was when people were sitting one behind the other. We had difficulty in detecting people in the event that the person's face was completely covered by the person sitting in front of him. As for the distance, it was measured correctly, but it depended on the detection of people. As shown in Fig. 11A, two people out of 4 were detected and the distance between them was measured. In Fig. 11B, all the people were detected and the distance between them was measured.

Fig. 11. Face detect when people are sitting one behind the other.

Finally, the results of observing the distance between people is presented, where laboratory, the distance between people was determined as 200 cm, and it was found that it 1923.55 pixels through experiments, so this distance was fixed and the condition was given based on it, we also found the calibration factor based on these results as shown below by using equation 4.

Calibration Factor = 200/1923.55 =0.1039744223 $cm/pixel$

Fig. 12.Monitor Social Distancing (A) Ed > Du (B) Ed < Du (C) Ed < Du with wearing a mask.

7. Conclusion

This study, a monitoring system for measuring the distance between people was developed, which will be useful during the pandemic. With the spread of epidemics among people, social distancing was an important solution that had positive outcomes, hence, it was a mandatory requirement. Violations of the safe distance could be detected through the monitoring system. The Viola-Jones algorithm was used to detect faces in the monitored places. The system was trained using 3 different numbers for the stages of the Cascade classifier, which were 5, 7, and 9, with three different numbers for the False Alarm Rate, 5%, 7.5% and 10%. The best detection result obtained was when using 9 stages with 5% of the False Alarm Rate as it concluded that the lower the value of the False Alarm Rate and the higher the number of stages for the Cascade classifier, the greater the accuracy of the detection of faces. After the faces were detected, the Euclidean distance was measured between the centers of the rectangles surrounding the discovered persons. During the experiments, the distance of 2 meters between individuals was imposed by most governments and the World Health Organization, and it was found that it is approximately 1923 pixels. 2 meters was considered as the threshold at which the Euclidean distance was compared with it after multiplying by calibration factor to determine the person's violation of social distance or not. The results obtained were adequate, and the side faces and those wearing the masks were detected, which the system was trained to detect the faces in all cases and obtain the best results.

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تطوير نظام رؤية آلي للحفاظ على التباعد الاجتماعي لمكافحة الوباء

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الخلاصة

يواجه العالم الآن أزمة طبية ، حيث أثر الوباء على ملايين الأشخاص حول العالم منذ ظهوره ، وهذا الوضع يحتاج إلى حل. استخدمت معظم الدول حلولاً مختلفة لمكافحة انتشار الوباء ، وفرضت منظمة الصحة العالمية بعض القواعد التي يجب الالتزام بها ، ومنها ارتداء الكمامات ، وحجر المصابين ، والمسافة الاجتماعية ، وهو من أهم الحلول التي قدمت نتائج جيدة لمواجهة الفيروس المستجد. تم تطوير العديد من الأنظمة التي تستخدم الذكاء الاصطناعي والتعلم العميق لتتبع التباعد الاجتماعي. في هذه الورقة ، تم اقتراح نظام قائم على التعلم العميق، والذي يتضمن مراقبة وكشف الأشخاص بالإضافة إلى قياس المسافة بينهم لمعرفة التباعد الاجتماعي بينهم. يتكون النظام المقترح من جزأين: الجزء الأول يكتشف وجوه الأشخاص باستخدام خوارزمية Viola-Jones ، وقمنا بتدريب مصنفات Cascade المستخدمة في الخوارزمية باستخدام احدى واصفات الميزات ليتم الكشف عن الوجوه الجانبية و المرتدية للكمامات و التي بدون التدريب تواجه صعوبة في الكشف عنها. الجزء الثاني و الذي يعتمد على الجزء الاول يقوم بقياس المسافة بين الاشخاص المكتشفين و ذلك بقياس المسافة الاقليدية بين مراكز المستطيلات المحيطة بالاشخاص المكتشفين . يتم قياس المسافة بين الاشخاص لمراقبة مدى التزامهم بالتباعد الاجتماعي. اظهرت النتائج التجريبية ان النظام المقترح يمكن ان يؤدي اداءً جيداً في التنفيذ على الصور لمراقبة التباعد بين الاشخاص.