COVID-19 PHYSICAL DISTANCE MONITORING SYSTEM USING REVERSE HOMOGRAPHIC TRANSFORMATION TECHNIQUE

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ABSTRACT: *The world has been disrupted due to an outbreak brought by coronavirus disease 2019 (COVID-19) with its deadly spread in over 180 countries worldwide. Vaccines are already available, however, physical distancing limits people's interactions giving no chance of the disease infecting other people. The use of surveillance video coupled with computer vision technology allows the implementation of physical distancing in public. It detects persons and calculates the distance between these people. The proposed framework, it utilizes YOLO v3 to automatically detect the person in real-time. Consequently, physical distance is computed using reverse homographic projection with the Euclidean distance formula. From the experimental results, YOLO v3, alongside an adjusted non-maximum suppression threshold displayed the best results in real-time detection of persons. Moreover, reverse homographic projection showed good performance in calculating the physical distance between people. To increase further the accuracy, it is recommended to try other algorithms for measuring the distance between people.*

Keywords: COVID-19, physical distancing, distance calculation, object detection, object tracking**.**

INTRODUCTION

Physical distancing gained prominence recently because of its crucial role in containing the coronavirus disease 2019 commonly referred to as COVID-19. Restricting face-to-face meetings with others is identified as the best way of reducing the spread of COVID-19. Limiting the people's interactions gives no chance of the disease infecting other people. International and local health organizations have pointed to its vital importance in stopping the transmission of COVID-19 among human hosts. Keeping space from others prevents the development of getting infected with deadly diseases. Such action of physical distancing especially in public areas crowded with different people must be observed as this not only slows down the spread of infectious diseases locally and across the country and world but also ultimately protects people and saves lives [1].

The COVID-A9 crisis has forced countries around the world to impose full lockdowns. These actions to contain COVID-19 have caused economic disruption. Recently, there are already areas that were given green light by their government to ease lockdown restrictions. However, the government recommended continually enforcing physical distancing in public areas as a low-cost non-pharmaceutical intervention to reduce the risk of transmitting COVID-19[2].

Given the positive impact of physical distancing on public human health during this COVID-19 crisis, this study chose to provide a solution that will assist in monitoring physical distancing in public areas using computer vision technology. With the rise of computer vision technology and artificial intelligence (AI), more studies were conducted that piloted object detection and tracking. With the use of different technologies detection and tracking of persons can be done through different approaches such as imaging [3]. Other systems utilize deep convolutional neural networks (CNN) for pedestrian detection. Human detection using visual surveillance systems is an established area of research. Recent advancements advocate the need for intelligent systems to detect and capture human activities [4].

For distance calculation, several methodologies are in place. Real-time distance determination algorithm using image sensor for use in an automobile environment. Implementation of the system utilizes C language complemented with OpenCV to optimize the implementation of common image processing functions [4]. Other approaches include the use of stereo vision-based pedestrian detection and distance measurement. A novel approach has been made to locate identical points in humans so that triangulation can be used for measuring distance [5].

METHODOLOGY

In the implementation of physical distance monitoring in public areas, object detection and tracking and distance calculation are two of the major subsystems to be considered. Figure 1 shows the overview of the system, the camera captures a video sequence of the people walking in the pathway. The region of interest is set by setting up points of the surveyed area. The system then detects the person in the given frame. The bounding box specifies that the camera was able to detect the person in the frame successfully. The bottom center of the bounding box provides proper distance measures regardless of the height of an individual.

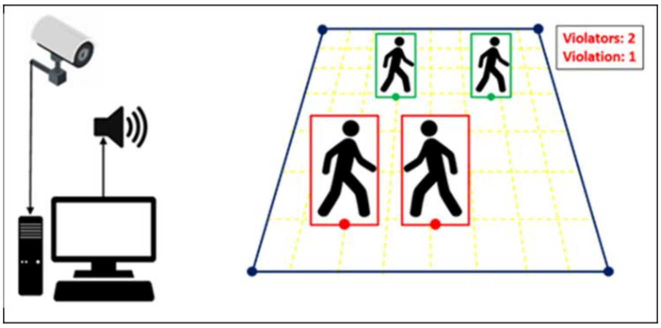

Figure 1: System Design

In measuring the distance, the bounding box provides coordinate points within the frame and the distance of these given points. These points are calculated for all available points within the frame and distance is calculated for each of the persons present in the frame. The bounding box color signifies the violation of recommended physical distance. The green bounding box denotes that there is no violation committed, on the other hand, the red bounding box signifies that there is a violation. The bounding box of each person detected will change from green to red the moment the system has detected below 6 feet distance between two or more persons. In the event, there is a violation of physical distancing, the speaker issues a warning to the public for strict enforcement of safe distance through audio feedback.

The process starts with getting a camera frame. From the camera frame, objects present will be detected and then localized. Localization is the process of predicting the object in an image as well as its boundaries. After localization, project pedestrian location based on the pixel in the camera. The floor area (plane) will undergo homographic transformation between two planes to retrieve the corresponding camera displacement that allows it to go from the first to the second plane view as shown in Figure 2.

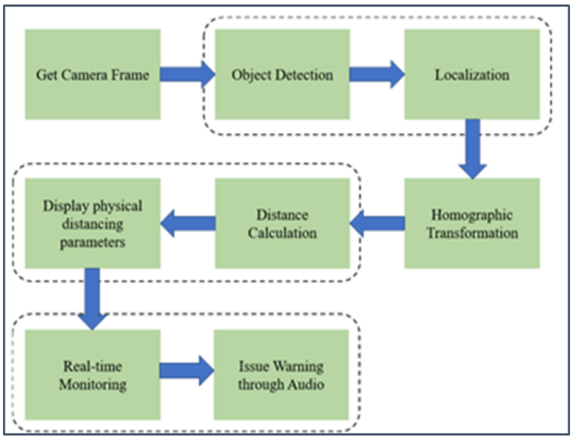

Figure 2: Block Diagram

The real-world distance calculation used is the reverse homographic projection formula with Euclidean distance calculation. This method requires the scene to be a complete rectangle.

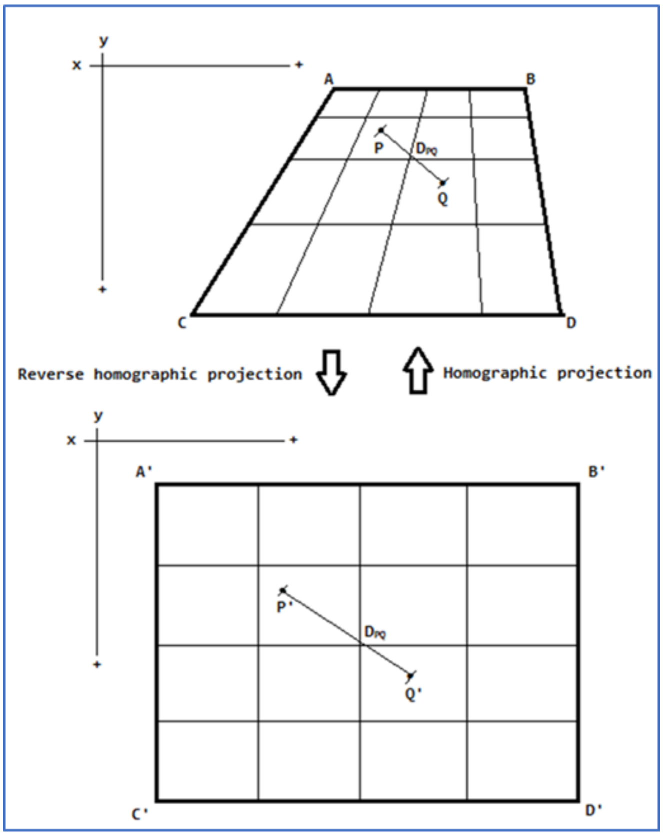

Figure 3: Reverse Homographic Projection

Let A, B, C, D as the projected quadrilateral, and A', B', C', D' as its real-world quadrilateral projection. Let point P and Q as the projected objects, P' and Q' as its real-world object projection, and D_{PQ} as their distance.

Consider a, b, d, e, g, h as homographic coefficients:

$$g' = \frac{[(D_x-A_x)*(D_y-C_y)] - [(D_x-C_x)*(D_y-A_y)]}{[(D_x-B_x)*(D_y-C_y)] - [(D_x-C_x)*(D_y-B_y)]} \quad (1)$$

$$h' = \frac{[(D_x-B_x)*(D_y-A_y)] - [(D_x-A_x)*(D_y-B_y)]}{[(D_x-B_x)*(D_y-C_y)] - [(D_x-C_x)*(D_y-B_y)]}$$

$$a = g' * (B_x - A_x)$$
$$b = h' * (C_x - A_x)$$
$$d = g' * (B_y - A_y)$$
$$e = h' * (C_y - A_y)$$
$$g = g' - 1$$
$$h = h' - 1$$

Homographic coefficients are calculated on input stream initialization. After the stream scene and projection configurations are ready. Consequently, Equation 2 solves for the homographic projection point **P** using the calculated coefficients.

$$P_x = \frac{\left(a*\frac{P'_x}{A'B'}\right)+\left(b*\frac{P'_y}{A'C'}\right)}{\left(g*\frac{P'_x}{A'B'}\right)+\left(h*\frac{P'_y}{A'C'}\right)+1}+A_x$$

(2)

$$P_y = \frac{\left(d*\frac{P'_x}{A'B'}\right)+\left(e*\frac{P'_y}{A'C'}\right)}{\left(g*\frac{P'_x}{A'B'}\right)+\left(h*\frac{P'_y}{A'C'}\right)+1}+A_y$$

After getting the values for P_x and P_y, solve for the reverse homographic projection point P' using the calculated coefficients. Equation 3 shows the following formula for reverse homographic projection.

$$P'_x = \frac{((P_x-A_x)*(e+h*A_y-h*P_y))-((P_y-A_y)*(b+h*A_x-h*P_x))}{((a+g*A_x-g*P_x)*(e+h*A_y-h*P_y))-((d+g*A_y-g*P_y)*(b+h*A_x-h*P_x))}*A'B'$$

(3)

$$P'_y = \frac{((P_y-A_y)*(a+g*A_x-g*P_x))-((P_x-A_x)*(d+g*A_y-g*P_y))}{((a+g*A_x-g*P_x)*(e+h*A_y-h*P_y))-((d+g*A_y-g*P_y)*(b+h*A_x-h*P_x))}*A'C'$$

Calculated values will then be used in solving the distance using the Euclidean distance formula in Equation 4.

$$D_{PQ} = \sqrt{(Q'_x-P'_x)^2+(Q'_y-P'_y)^2} \quad (4)$$

$$D_{PQ} = \sqrt{(Q'_x - P'_x)^2 + (Q'_y - P'_y)^2}$$

Final calculation accuracy will vary greatly on projection configuration and person detection accuracy.

Test cases were devised to check the accuracy of person detection. Three scenarios were chosen namely: one person walking along the pathway, two persons walking along the pathway with two variations: persons in line and a person side by side, and lastly four persons walking along the pathway.

Case 1. One person walking along the pathway. This case involves the person walking along the pathway toward and outward the camera position as shown in Figure 4.

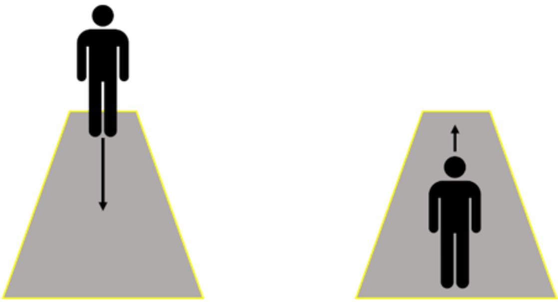

Figure 4: One person walking along the pathway

Case 2. Two persons walking along the pathway. This case involves two persons walking along the pathway toward and outwards the camera position. The tested distance between them is 3 feet (minimum distance). Two scenarios were tested, two people walking side by side and two people walking in line as shown in Figure 5. The same test was conducted but this time the distance between them is 2 feet. This is to check the violation distance as shown in Figure 6.

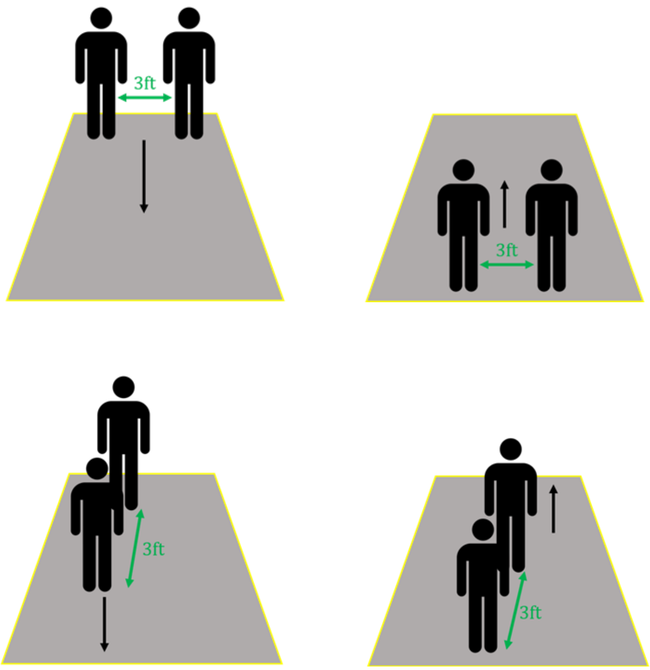

Figure 5: Two persons walking with no violation

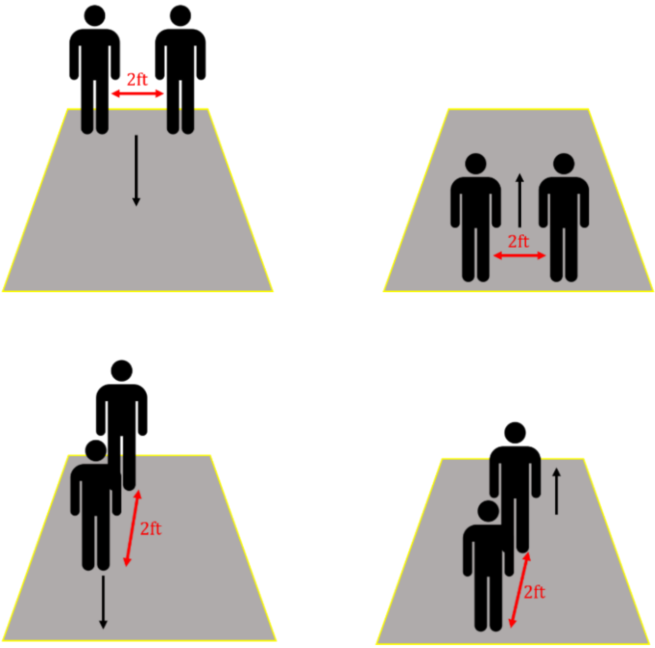

Figure 6: Two persons walking with a violation

Case 3. Four persons walking along the pathway. This case involves four persons walking along the pathway toward and outward the camera position. The tested distance in between is 3 feet (minimum distance) and 2 feet sideward and forward as shown in Figure 7 and Figure 8.

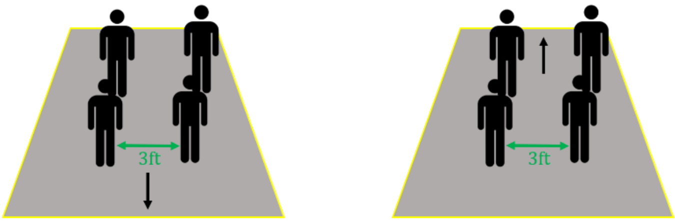

Figure 7: Four persons with 3 feet distance

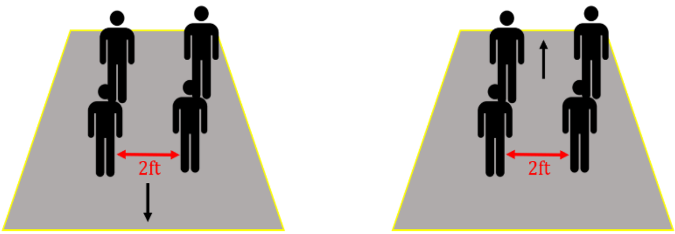

Figure 8: Four persons with 2 feet distance

RESULTS AND FINDINGS

To summarize and show the performance of person detection and distance accuracy. Table 1 shows the accuracy of the system based on the total number of frames extracted from a real-time video stream of an IP camera. This testing includes one person walking along the pathway, two persons walking along the pathway in-line and side by side, and four persons walking along the pathway towards and outward the camera position. The distances tested were a minimum of 3 feet distance and another 2 feet distance as a negative input.

For the first test, the one-person detection, the system shows 100% detection accuracy of the person from the first frame up to the last frame. This involves 10 different videos detects of individual persons with 819 total frames extracted. This does not have distance detection accuracy since it only has one person in the video frame.

The second test involves two tests, two persons walking along the pathway in line and side by side. For the two persons walking along the pathway side by side, the system shows 99.17% for person detection and 89.26% for distance accuracy. This accuracy is for both 3 feet distance, which is the minimum distance calibrated for the system, and a 2 feet distance as the negative input. This can be seen in Figures 9 and 10.

Table 1: Accuracy Result of the System

Test Case	Total No. of Frames	Detection		Distance Violation		Accuracy	
		Correct	Incorrect	Correct	Incorrect	Detection	Distance
One (1) Person	819	819	0	n/a	n/a	100.0	n/a
Two (2) Persons in Line	830	172	658	496	334	20.72	59.76
Two (2) Persons Side by Side	605	600	5	540	61	99.17	89.26
Four (4) Persons	306	27	279	238	68	8.82	77.78

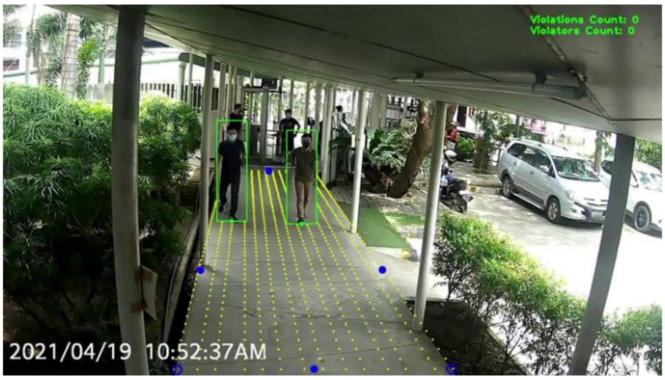

Figure 9: Two persons walking side by side along the pathway with 3 feet distance (safe distance)

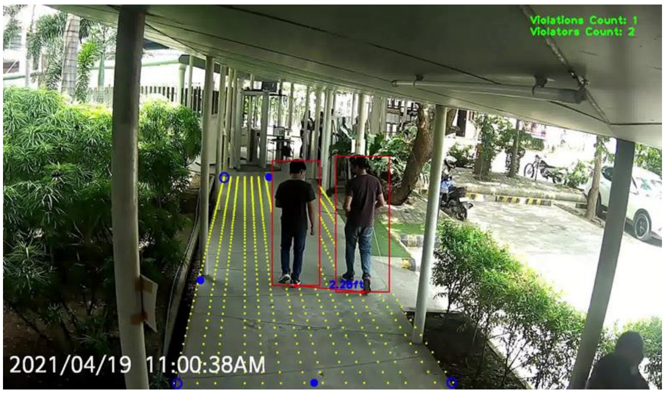

Figure 10: Two persons walking side by side along the pathway with 2 feet distance (violated distance)

For the two persons walking along the pathway in line, the system shows 20.72% for person detection and 59.76% for distance accuracy. The accuracy of person detection gives a very low detection rate due to occlusion. The camera position is placed at an 8-feet distance above the ground and angled at 45° from the horizontal line. Also, the distance of 3 feet between the two persons is close for the system to detect the two individuals as shown in Figure 11.

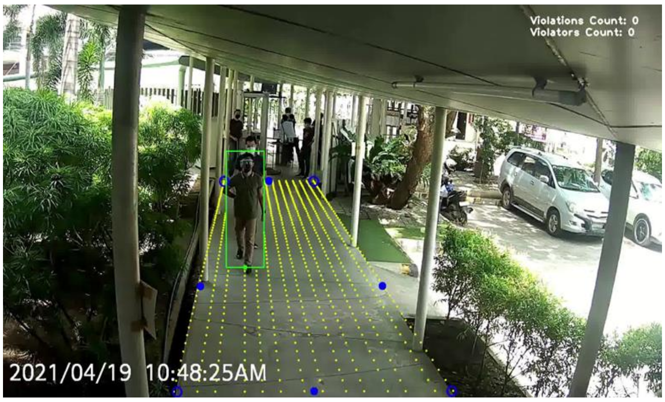

Figure 11. Two persons walking in line along the pathway at 3 feet distance (safe distance)

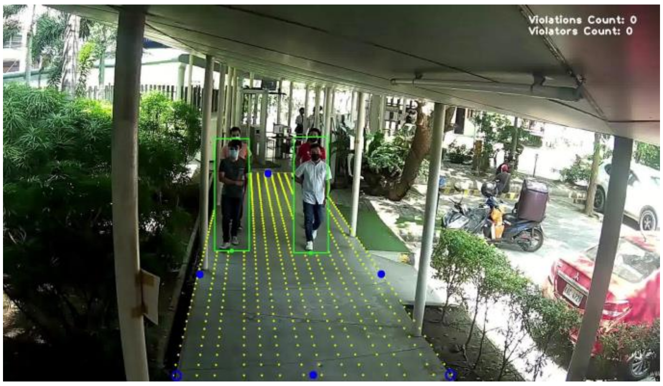

Figure 12: Four persons walking along the pathway with 3 feet distance

Four persons walking along the pathway towards and outwards the camera position, the system shows 8.82% for person detection and 77.78% for distance accuracy. The same problem goes for four-person detection with fixed 3-feet and 2-feet distances; there was a very low detection rate due to occlusion as shown in Figure 12.

CONCLUSIONS & RECOMMENDATIONS

The article proposed an efficient real-time deep learning-based framework to automate the process of monitoring physical distancing via object detection and tracking approaches. YOLO v3 is used for object detection and tracking. Every violation is detected and recorded and audio feedback is given to people walking in the pathway. Reverse homographic projection is an algorithm capable of measuring the distance without the use of a specialized camera.

The methodology carried out in this study opened up more opportunities to further enhance the system. Some recommendations and future directions include:

- Improvement of the design of the detection system by using a specialized cameras such as stereo cameras for distance calculation.
- Use of different distance calculation algorithms to enhance the calculation.
- Use of different optimization algorithms to optimize the machine learning model for the classification persons.

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