JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 3161-3166
https://publishoa.com
ISSN: 1309-3452

Social Distancing Monitoring System Based on Image Processing

[1] Navind Sivarajoo, [2] Mohd Azwarie Mat Dzahir, [1] Shaharil bin Mad Saad, [1] Wan Aliff Abdul Saad, [1] Muhammad Danial, [1] Zair Asrar Ahmad

[1]*School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*

[2] *Faculty of Built Environment & Surveying, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*

mohdazwarie@utm.my

ABSTRACT

This project is about using Raspberry Pi to create the monitoring system for the detection of social distancing status for queueing up situations in public places. The objective of conducting this study is to develop a social distancing monitoring system based on Image Processing, calculate the distance of 1 meter based on the image pixel of queueing up people, and to compare the best position/angle of the camera location to get a good 1-meter accuracy. The scopes of the project are the system only focuses on queueing up situation, the data accuracy is limited to the experiment setup and Raspberry Pi Camera Board use, and the subject of people queueing up is pre-defined in this project. Raspberry Pi associated with its camera module is used for the monitoring purpose. OpenCV and Python is implemented to develop the program associated with Caffe models for people detection. The best angle for accurate detection is from side view and the system can run on real-time when tested over 10 runs. The main suggestions to improve the overall system is by using a camera with higher resolution and adding more samples for the detection.

Index Terms — Raspberry Pi, Image Processing, OpenCV, Python, and Caffe models.

I. INTRODUCTION

In this recent pandemic of COVID-19, people in countries all over the world are suffering in terms of health and financial, while many of them have died due to the difficulty faced in breaking the chain of the coronavirus spread. Government is trying their best to have the situation in control by implying Movement Control Order (MCO), where movement of public are restricted to several distances. People are getting bored staying at home in this situation where they feel a loss of freedom. They are also not following proper Standard Operating Procedure (SOP) as implemented by the government in public areas such as not wearing safety mask, not following social distancing, and not obeying the distance limit they are allowed to travel.

Therefore, in this study we are interested to develop a social distancing monitoring system based on Image Processing by using Raspberry Pi to monitor social distancing violations in public places, especially in queueing up situations outside banks, shopping complexes and bus terminals. There are two ways of monitoring social distancing that is via a manual or an automatic solution. The manual method is already being applied in public places like shopping mall where an operator resolves the situation of people being in close contact by some approaches. They will adjust the queueing up positions and instructing people to follow social distancing. Although this approach seems simple to be applied, we require an efficient monitoring system for a long-term usage, which refers to an automated social distancing system in this context [1].

II. LITERATURE REVIEW

Both the pictures in Figure 1 shows how the proposal of the research team on using Artificial Intelligence to create a Computer Vision, which will effectively slow down the spread of the coronavirus by automatically monitoring and detecting the violations of people in maintaining social distancing.

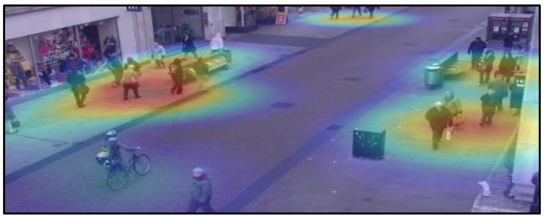
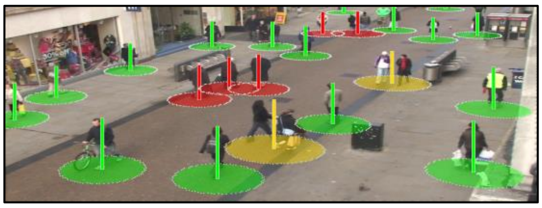
(a)  (b) 

Figure 1: Detection of people walking situation public CCTV camera. (a) Social distancing monitoring; (b) Highlighting infection risk zones [2]

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Volume 13, No. 3, 2022, p. 3161-3166
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They created this system using Deep Neural Network (DNN) model for detecting and tracking people associated with DeepSOCIAL, to estimate the distance between them. The research team did back up their results with vast repetition of the detections in both indoor and outdoor situations. They introduce a three-stage model where the system can perform people detection, tracking, and distance measurement efficiently. The system is ideal for all types of CCTV surveillance cameras equipped with any resolutions from VGA to Full-HD.
Based on Figure 2, the system input starts with a CCTV surveillance camera collecting real-time video for the people walking down in public places and passes it to the Deep Nueral Network (DNN) model. This will result in detection of human in bounding boxes accurately as the model used as stated will effectively detect the classes and location. The model is associated with well pre trained datasets such as MS COCO and Google Open Image dataset for improved accuracy in detection. This is because the system should be able to detect diversity in age and gender with millions of annotations and marking. The research is carried on with seven different DNN models to be compared and evaluated for the accuracy in people detection.

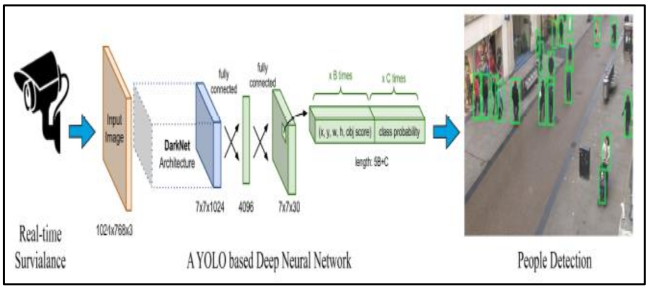


Figure 2: The overall setup for people detection [2]

In a study conducted based on IoT implementation for developing social distancing monitoring system, it was highly recommended that this way of setup will be much efficient and affordable in tackling the pandemic of COVID-19. The Raspberry Pi-2 computer with a single board equipped with camera is used to apply the object detection algorithms in this project as shown in Figure 3. The main aim of this study is to offer a solution which will ensure high safety level of real-time monitoring for IoT devices [3].

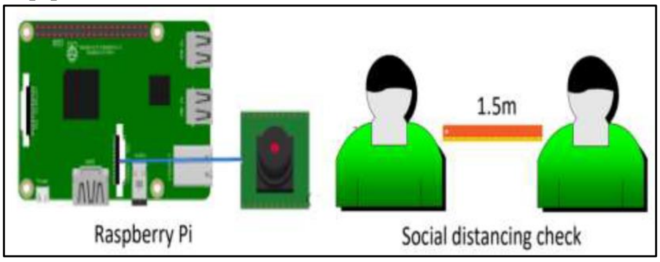
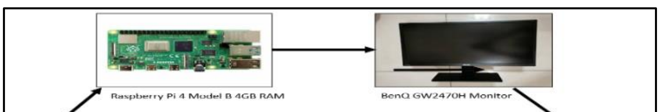


Figure 3: The overall setup for people detection [3]

The study on IoT-based social distancing monitoring system in identifying the behavior of people in following SOP in business and public places implies the setup that uses Raspberry Pi and its camera module. The system is enclosed in a floor space of compact retail businesses. The study concluded that the system proposed is adequate to evaluate the social distancing violations in a compact area and send information wirelessly, where the setup can be further modified in future that it would be able to cover a larger space of working area [4]. High-speed GPU applications supported CUDA, and OpenCL are in the process of improving for better performance. The testing phase was conducted for the detection system, and it works well in detecting social distancing violations by also providing the number for it in the live feed [5]. Caffe model is a wholly open-source framework which offers great flexibility to Deep Learning. The code is developed in C++, utilizing CUDA for GPU computation, and possesses great association with Python and MATLAB. There are some key highlights of implementing Caffe models in Deep Learning. First, it has great modularity in permitting simple extension to new data formats and network layers. It has a great support for changing from CPU to GPU in a single function. Then, it provides a good test coverage for researchers applying the codes by having tests for every module that will enhance the work. Besides, the friendly binding with Python serves for instant prototyping with existing codes and to build networks by revealing the solver module for new practices. Caffe also offers pre-trained reference models for visual recognition, especially R-CNN detection model [6][7][8].

III. OVERALL SYSTEM PROPOSED

Based on Figure 4, the Raspberry Pi 5MP Camera Board is first attached in the port of Raspberry Pi Model B 4GB RAM.



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Volume 13, No. 3, 2022, p. 3161-3166
https://publishoa.com
ISSN: 1309-3452

Then, the bigger task of creating the coding for developing the detection system is done in the Thonny, Python IDE platform which serves as the basic for this system. The OpenCV library is used here since the detection is made to be a real-time computer vision. Caffe models, which is a Deep Learning framework is implemented in the coding to detect only people with a specific class ID allocated.

Figure 4: The overall system proposed for the study

The distance is marked for 1 meter using a double-sided for each person to stand in the testing phase as shown in Figure 5. The pattern for sticking the tape in a long horizontal manner is exampled from what government implements.

Figure 5: Validation of 1 meter distance.

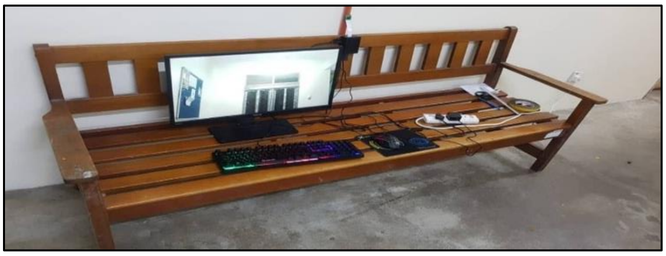

Figure 6: The overall designed setup

The equations used to calculate the distance between two detected persons in this project is implied in the python coding. The parameters are calculated step by step from creating the bounding box and evaluating the distance. First, the center point of the bounding box to be drawn on a detected person is determined in terms of x and y coordinates:

$$\text{Midpoint of x} - \text{coordinate} \ = \ (\text{startX} \ + \ \text{endX}) \ / \ 2) \quad (1)$$
$$\text{Midpoint of y} - \text{coordinate} \ = \ (\text{startY} + \ \text{endY}) \ / \ 2) \quad (2)$$

Then, the height of the bounding box for a single detected person is calculated by subtracting the height taken at the top of the head with the point at bottom of the feet:

$$\text{Height} \ = \ (\text{endY} - \text{startY}) \qquad (3)$$

Next, the distance from the camera to the detected person is calculated using focal length set at the initial part of the coding. The focal length used in this study is 615

$$\text{Distance} \ = \ (\text{Focal\_length} \ * \ 165) \ / \ \text{height} \qquad (4)$$

After that, the center point of the bounding box to be drawn on each person is calculated in cm using the previously obtained values for midX and midY:

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https://publishoa.com
ISSN: 1309-3452

$$\text{Midpoint of x} - \text{coordinate in cm} = (\text{midX} * \text{distance}) \,/\, \text{Focal\_length} \tag{5}$$
$$\text{Midpoint of y} - \text{coordinate in cm} = (\text{midY} * \text{distance}) \,/\, \text{Focal\_length} \tag{6}$$

Finally, the distance between two adjacent persons is calculated using squared distance:

$$\text{Safe distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{7}$$

IV. Result & Analysis

For ensuring a greater accuracy, the program is tested by having three persons in a frame as shown in Figure 7. This will give an idea of maybe two persons are close to each other, but one person is slightly apart from them creating a safe situation. This process will help us to identify that only the violating people are drawn with a red bounding box, where a warning message will be created saying they should be moving away from each other. The output again showed an accurate detection by drawing two red bounding boxes on people who are too close to each other and need to slightly move away from each other but the person who is maintaining a safe distancing is drawn a green bounding box.

Figure 7: Bounding box drawn for detection on three people

The detection system was tested for the greater accuracy in drawing the appropriate bounding box colors based on the computed distance. This was done by adjusting the camera angle in different ways, which is in a side view and front view. The results of this detection will lead us to choose the best camera angle to work with and to further the repetition to ensure consistency. First, the 5 different situations planned for arrangement in the queue with the camera detecting the people from side view was executed as follows.

A. Side View Detection

The first arrangement planned for the detection is making 5 people standing very close to each other where they violate the 1-meter social distancing as shown in Figure 8. The camera successfully captured all 5 of them and drawn the red bounding box for everyone as the computed distance between each of them is less than 1 meter. This detection was considered accurate as it gave the output as expected.

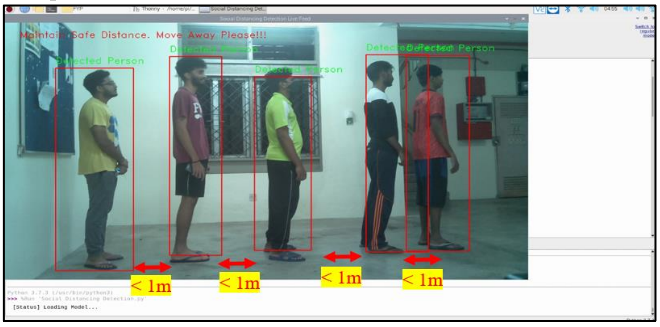

Figure 8: The detection result for an arrangement of 5 people with unsafe distancing from side view

B. Front View Detection

For the first arrangement, the output of the system is three red bounding boxes being drawn on the people who maintain an unsafe distancing of less than 1 meter.

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Figure 9: The detection result for an arrangement of 5 people with unsafe distancing from front view

However, the last person in the queue is detected by being drawn a green bounding box where it should be red in color as shown in Figure 9. This happens because the fourth person in the queue is not detected in the system leading to the last person in the queue to be detected as maintaining a safe distancing from the three violating persons in front. Based on the results discussed in the previous sections, the output of detection by drawing the appropriate bounding boxes based on the distance computed is very accurate when camera is placed for a side view. For all 5 arrangements made, the system can produce the expected output by capturing and drawing separate bounding boxes with different color codes based on the distancing people maintain. On the other hand, the social distancing detection output for the arrangements captured from the front view is less accurate as it produced results with inconsistent drawing of the bounding box for the people detected. It produces clearly seen errors such as missed person on detection, one bounding box for two people and red bounding boxes drawn for people maintaining safe distancing with each other.

C. Real-Time Monitoring on Detection with Side View

The social distancing detection by having side view as the best camera angle is planned to be continued for real-time monitoring. As in previous results, the detection is done just on a single image captured by arranging the people in different positions and observing the expected output. However, in this section, it is about real-time monitoring where the system will run in a loop, where it will capture up to 5 images in a single run with 5 seconds interval for each image as initially set in the coding. The arrangements for the people to stand is same as used in previous detections for both side and front view. This process is to ensure that the system possesses the capability to operate efficiently in a real-life situation where the people standing in queue tend to change their position in short intervals. The system needs to quickly capture and process the image for detection before proceeding to the next one in a quick timeframe. For this testing, the side view detection is carried out for around 10 times in real-time monitoring to ensure the system is accurate in producing results and to check the ability to continue running for detection as the process is on loop. The results of the detection for the first run of the real-time monitoring will be discussed in the upcoming section.

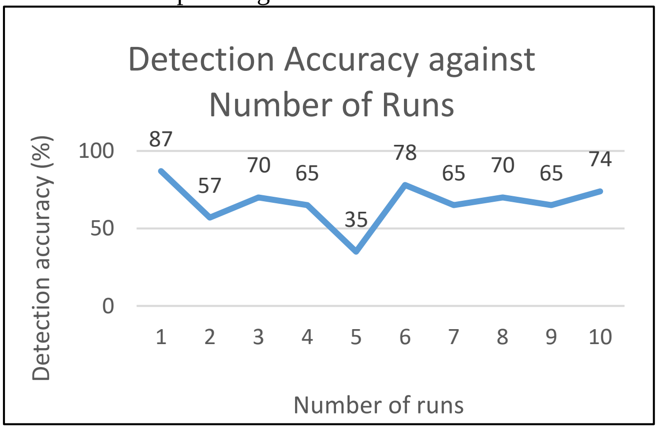

Figure 10: The graph of detection accuracy against number of runs

Based on the graph plotted as in Figure 10, the trend is fluctuating for the detection accuracy of the system to capture and process the images by drawing appropriate bounding boxes based on the distance computed. The highest accuracy is obtained in the first run with 87% and the lowest accuracy is 35% at 5th run in the real-time monitoring testing.

In a study conducted, the social distancing detection performance was tested using only two people with a prediction that it would drop, if more people are used in the range covered by the camera. The accuracy of the detection fluctuates based on the distance of object viewed from camera as it varies with respect to the earlier calculated ratio between pixels and meters. It is also suggested that the accuracy of the detection becomes greater when the resolution increases. Then, the study also recommends that applying various Deep Learning and computer vision advancements associated with Raspberry Pi would help to obtain a higher framerate in future projects [9][10].

Moreover, the detection accuracy can be further improved by integrating with other detection parameters such as mask detection and human body temperature detection. Then, the system could be enhanced by upgrading the computing

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capability of the hardware and performing calibration on the camera view [11].

CONCLUSION

In this COVID-19 pandemic, it is very useful and efficient to implement a social distancing monitoring system as discussed in public places. The testing conducted for the social distancing detection achieved the objectives and yielded in accurate results by placing the camera in a side view. In addition, the system is run on real-time monitoring over 10 runs and a graph is plotted to analyze the detection accuracy obtained. It is noted that the highest accuracy is obtained in the first run with 87% and the trend of the graph fluctuated. This is due to some errors present in the results obtained from the detection done such as people being missed out from detection and inappropriate color of bounding boxes drawn on them. The system could be improved by the referring to the limitations and suggestions provided in previous research which will be discussed on the next section. The system created for the detection is much affordable and simple to assemble in nature. This project has helped much in gaining knowledge and learning new things, especially on image processing and computer vision which would benefit everyone if used in wide range of applications. The basic understanding on the functionality of every component used to setup the overall system and the execution time is prioritized to achieve the scopes of the project. The project flowchart developed earlier is vital in guiding the process flow of setting up the overall system which will yield in an organized work. In short, schools should implement computer vision subject to produce tech savvy students.

ACKNOWLEDGEMENT

The authors would like to acknowledge the financial sponsorship provided by Universiti Teknologi Malaysia (UTM) through university research grant, No: 4C489, 16J14 and 20J83.

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