Developing Smart COVID-19 Social Distancing Surveillance Drone using YOLO

*Implemented in Robot Operating System simulation environment

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***Abstract*—The Novel Coronavirus, termed as COVID-19 outbreak, is faced by almost all countries in the world. It spread through communal interaction between people, especially in densely populated areas. An effort to prevent Covid-19 transmission is social distancing regulation. However, this policy is not obeyed by the public, so the government needs to supervise the movement and people's interaction. The government needs a crowd surveillance system that can detect people's presence, identify the crowd, and give social distancing warnings. Therefore, we propose a drone that has the ability of localization, navigation, people detection, crowd identifier, and social distancing warning. We utilize YOLO-v3 to detect people and define adaptive social distancing detector. In this paper, we implemented a road segmentation on the IRIS PX4 drone in the Robot Operating System and Gazebo simulation. The proposed system also successfully demonstrated people and crowd detection with varying degrees of the crowd. The system obtained crowd detection accuracy is around 90% and expected to be readily implemented on real hardware drones and tested in real environments.**

***Index Terms*—COVID-19, Social Distancing, Drone, YOLO, Robot Operating System**

I. Introduction

Covid-19 outbreak has not shown any signs of being over. Globally, this virus affects 216 countries with a total confirmed more than 7 million people, and there are 400 thousand people who died. However, the community has already started to move because of economic needs, which is already urgent. A number of regions have begun to open lockdowns to allow residents to reactivate but by still implementing strict health protocols. This is encouraging local governments to promote new regulations to carry out social distancing. This regulation is made so that people do not transmit the virus and the number of victims can be suppressed. Therefore, monitoring system is needed to reduce the risk of transmission of the virus.

The monitoring of social distancing is carried out by the police by conduct routine patrols at points that have the potential to crowd. This scheme provokes risks in transmitting the disease to the personnel involved. Other reason, such as limited personnel and coverage area need to be considered. This is very ineffective, dangerous, and costly.

A comprehensive study by Chamola [1], summarize an extensive exploration about the use of the latest technology such as Artificial Intelligence (AI), Internet of Things (IoT), Robotics, and Unmanned Aerial Vehicles (UAVs) to minimize the impact of Covid-19. In [2], research has been conducted on the detection of COVID-19 by using an infrared thermometer to check human body temperature, as well as using Virtual Reality to conduct monitoring that is seen in the first-person view.

Some research focus on social distancing monitoring system. The system utilize camera static that embedded with people detection algorithm. Punn [3] utilized YOLOv3 to detect people in a road or limited area. Yang [4] also develop social distancing warning system using monocular camera. It utilize Faster R-CNN to detect pedestrian in a static area. However, social distancing surveillance system have to cover more wide area. To overcome that limitation, some research proposed robot as an agent to monitor.

Zhanjing proposed robots as an agent to reduce the COVID-19 virus spreading [5]. In [1], some research also said that robot especially drone has a huge potential to become an agent that can mitigate Covid-19 impact. Drone can be equipped with several sensor such as camera, thermal, and lidar. Drone can be used to do monitoring, surveillance, screening, announcing, to disinfecting area even delivering medical supply. By using drones, social distancing surveillance can be carried out remotely and spread evenly to public areas to be monitored 24 hours effectively. Thus, the costs using manpower can be replaced by drone fuel which is cheaper.

A single drone can oversee a wide-open area because a drone can fly right above the target, usually it called a top-view or bird-view. This position makes it easy for drones to see distance between humans more accurately than any other view such as front view. However, there are no research that develop drone with smart capability to do social distancing surveillance system. Ramadass [6] applied deep learning YOLO3 to monitor social distancing but it did not explained how to design or implemented it in a drone. Hence, implementation of smart social distancing surveillance system using drone is an important and urgent study.

The proposed system aims to design the COVID-19 social distancing surveillance system effectively, efficiently, and safely. This paper design smart drone as a agent to detect people, measure distance between people, and give a notification about social distancing violation. The system utilized the YOLO-v3-tiny which is the fast object detection algorithm [7]. This algorithm using lightweight detector that fits embedded system which has small computation [8].

The social distancing surveillance system also detects crowd based on the distance between people. The drone use global positioning system to know its position that can be forwarded to the supervisor together with a report and attached photos as evidence. This paper is a preliminary step of our system, we first implement detection and social distancing algorithm in Robot Operating System. Then, we prove our concept by implementing methodology using model of IRIS PX4 drone and simulating it in JDERobot using Gazebo environment.

The rest of this paper is organized as follow: Section 2 present literature study that become foundation to design our system. Section 3 discusses proposed framework. Section 4 explain the experiment and result. The last, section 5 draws the conclusions and future work.

II. The Proposed System

We design a Smart Social Distancing Surveillance system using a drone to identify violations of social distancing policy. The drone detect people and identify if there are two people or more who are close each other at a certain distance. The drone is embedded with global positioning system that localizes the observed area and also detect road by flying over it using navigation scheme. The proposed framework consist of important part namely, Object Detector, drone agent, localization, navigation, and Social Distancing System. Figure 1 shows the proposed framework.

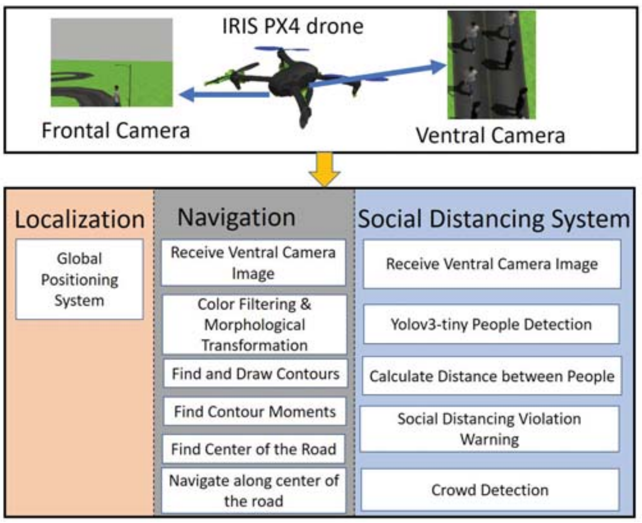

Fig. 1. The proposed social distancing surveillance framework

A. YOLO for Object Detector

Object detection is one method in computer vision that aims to localize objects in an image that contains more than one object. YOLO (You Only Look Once) is an algorithm that uses a convolutional neural network model to detect objects [9] and run in real-time. In this paper, we utilized YOLO-v3 [7] with a feature extraction architecture called Darknet-53. This architecture contains 53 convolution layers, followed by the batch normalization layer and the Leaky ReLU activation function.

B. Drone Iris PX4 as agent

IRIS PX4 is a four rotor drone from Pixhawk autopilot system which support all-in-one autonomous drone. PX4 is powerful cross-platform ground station that supported Robot Operating System based controller. Figure 1 top part,shows the IRIS PX4 drone model in Gazebo. PX4 is ready for aerial imaging application because it is already installed with camera. PX4 has one frontal as navigation and obstacles avoidance sensor. PX4 is also equipped with a ventral camera that are useful to observe people movement underneath it with top view position.

C. Drone Localization and Navigation

The propose framework uses existing Global Positioning System to localize drone position. Furthermore, our navigation scheme guide drone to follow road that seen under the drone. Navigation scheme begin after drone take off. We receive image from ventral camera and do color filtering using OpenCV to segment the road. After that, we transform the image morphological to reduce noise. Next, we find contour and define its moments to obtain segmented road. After road successfully segmented, we calculate center of the road.

Road segmentation produce white area and calculate the center of the road (red dot) to guide movement command. We define simple velocity command which track road while keep maintaining the red dot in the center position. Beside ventral camera, drone also use frontal camera as sensor for obstacles avoidance.

D. Social Distancing System

Social Distancing System consist of three essential feature such as people detection, social distancing violation, and crowd detection.

1) People Detection: Drone uses image data from ventral camera to detect people. We train and fine tuned several input image to adapt Yolov3-tiny with ventral image. Figure 2 depicts training data to train Yolov3-tiny model. We generate training data from different altitude level and ground type to adapt the environment.

Drone detect people as a bounding box. Then, the method defines the central point of bounding box by dividing the height and weight values. The box is used for distance measurement in the next step.

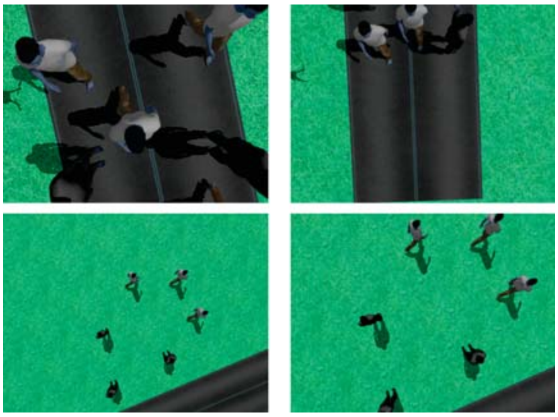

Fig. 2. Training dataset for Yolov3-tiny

2) Distance Calculation: Drone calculate distance between two people nearby using Euclidean distance formulation. Assuming there are two coordinates of people bounding box (x_1, y_1) and (x_2, y_2), then the distance d is obtained in equation 1:

$$d = \sqrt{((x_2 - x_1)^2 + (y_2 - y_1)^2)} \qquad (1)$$

In this research, we utilized Pinhole algorithm principle to determined object position relative to drone under ventral camera which refer to [10].

3) Social Distancing Violation Warning: Social distancing warning system is active when someone is at a certain distance from other people. In this paper, we define 100 px as threshold to someone considering to violate social distance or not. If the distance exceeds 100 px (pixels), then the bounding box color turns into green. Conversely, if less than 100px, the bounding box is red. Therefore, the system can calibrated one pixel in this simulation into real-word distance in meters using constants calibration K that inspired from area expansion principle in the previous work [11].

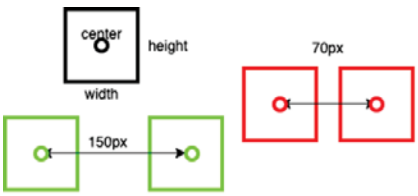

Fig. 3. Illustration of proposed social distance violation warning in pixel units.

4) Crowd Detection: Drone also has capability to detect one or more crowd in a area. This capability is extended feature from distance between people. If drone identify the distance between two or more people is more than 100 px, drone will classify as crowd.

E. Simulation Architecture

This research tested the proposed social distancing surveillance system in a simulated environment. We use simulation framework from JdeRobot [12]. This framework is Robot Operating System (ROS) based that provide simulation under Gazebo package. This simulation presents drone IRIS PX4 model, environment modeling such as road, grass, house, light, and sun. It also provide integration with mavros package ("mavros_px4_sitl_launch") as communication node for ROS with Ground Control Station. Then, we add people model to prove our detection method. For basic drone control system, we utilized mavros package. Figure 4 shows several ROS package and node that involved in our simulation. It consist of /gazebo, /mavros, /iris drone, standard velocity command (/twist, /take off, and /land), and /inteface which interfacing our method in processing image raw from camera.

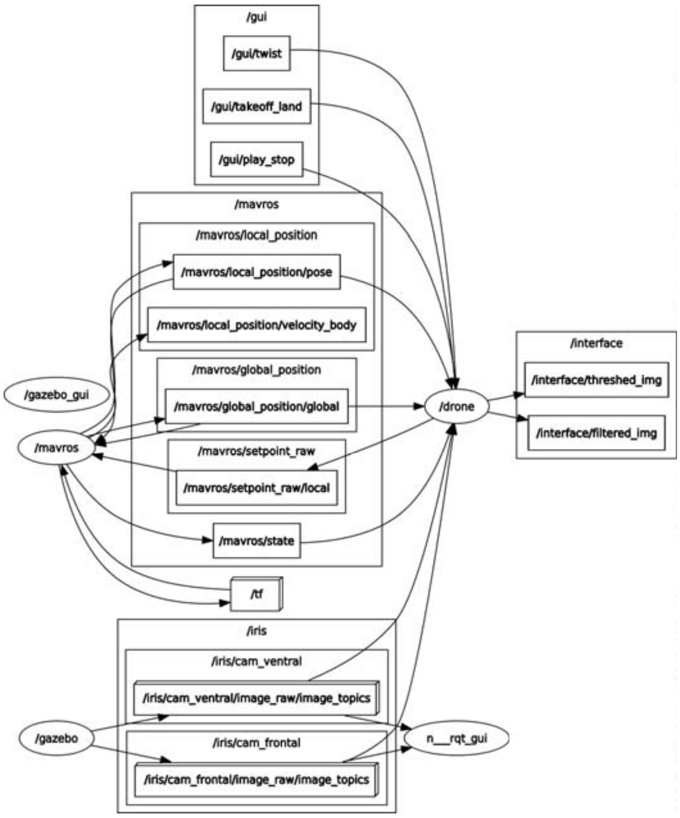

Fig. 4. ROS package and node that involved in proposed framework

The experiments were run using the following PC specifications as 32GB RAM and NVIDIA RTX 2080TI with 11GB VGA RAM. The programming language used is python version 2.7 with OpenCV version 3.2.

F. Real World Target Localization

The environment used in this research conducted in Gazebo environment. Thus, the proposed method need to localize the target so that the system can be validated to mimic real world scenario. Therefore, the x, y, and z coordinate of the target in Gazebo environment can be calibrated to real world coordinate. The scenario between a drone and a person can be illustrated in Figure 7.

The target need to be localized first in Gazebo environment. To do so, suppose the distance between drone and a person is ds. Using the distance formula between two points in the three-dimensional space, ds can be defined as:

$$ds^2 = dx^2 + dy^2 + dz^2 \tag{2}$$

where,
ds = straight distance between drone and person
dx, dy, dz = distance between drone and person in xyz-axis

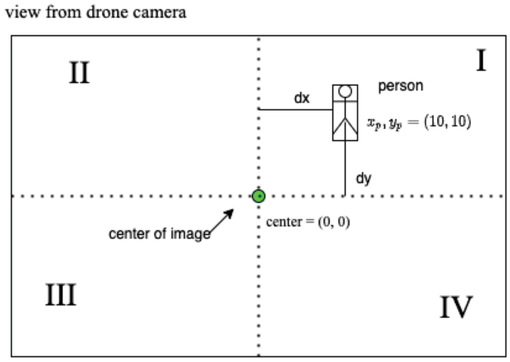

Fig. 5. Camera ventral view in 2D image taken from drone

The drone camera will capture the person in from drone camera 2D image which the image is divided into four quadrants based on Figure 8. We will use this information to localize the person and calibrate the coordinate position to meters. Therefore, the image which measured in pixels is calibrated to real-world measure in meters. We assume there is a K value which obtained by calibrating the pixel units and meters unit. Since dx and dy in 2D image can be calculated directly, the calibrated dx and dy is formulated as:

$$dx_{calibrated} = |K * dx| \cap dy_{calibrated} = |K * dy| \tag{3}$$

Furthermore, we proposed the distance between drone to person head since we want to know how far the drone to the person is. It is also to make sure if the drone doesn't get too far to the person since it can affect the ventral camera calibration. We use [11] to formulate the distance between drone and person as ds. The equation we use is below.

$$ds_{calibrated} = \frac{area_{BB_0} - area_{BB_{drone}}}{area_{BB_0} \cdot \beta} \tag{4}$$

Where,
$area_{BB_0}$ = bounding box area of person in $pixel^2$
$area_{BB_{drone}}$ = bounding box area of reference target in $pixel^2$
β = coefficient of bounding box expansion in $meters/pixel^2$
$ds_{calibrated}$ = distance between drone to person in meters

β value is assumed $5.10^{-2} meters/pixel^2$. The $area_{BB_0}$ variabel is obtained by make drone closer to person and tuned to 9600 $pixel^2$. Since our focus was distance between person in the ground, we just calculate the distance similar with equation 1 as $dp_{calibrated}$.

$$dp^2_{calibrated} = \sqrt{((dx_{calibrated_2} - dx_{calibrated_1})^2 + \cap (dy_{calibrated_1} - dy_{calibrated_2})^2)} \tag{5}$$

III. Result and Discussion

In this research, we conduct three experiment to prove our proposed Covid-19 social distancing surveillance. We evaluate localization and navigation scheme, people detection performance, social distancing violation warning, and crowd detection performance.

A. Localization and Navigation Scheme

Localization and navigation ability is important in surveillance system. Drone localize its position using Global Positioning System then run navigation scheme to monitoring area. In this method, drone detects the road from ventral camera, segments it, and following the segmented road. Figure 6 shows drone can segment road by producing white area in the filtered image box. Drone also find road contour that is marked as the green line. Based on 7, we can conclude that drone can segment road well, do localization, road follow navigation, and produce surveillance path based on defined map.

Fig. 6. Road segmentation result

B. People Detection

The proposed people detection has two scenario namely fly oversees the road and sidewalk. While drone segment the road, it detects people using fined-tuned Yolov3-tiny. We tested input data from ventral camera. Figure 8 show drone can detect people on the road. We can see that camera raw data is in left side (ventral camera) and the people detection is in the right side (Threshold Image) which is marked by red and green bounding. To evaluate people detection quantitatively, we count hit and miss in some scenario based on the number of people. Table I show hit rate of people detection above 90% where the method successfully detect for case 1 and 2, then detection method just mis 1 people for each case 3 and 4.

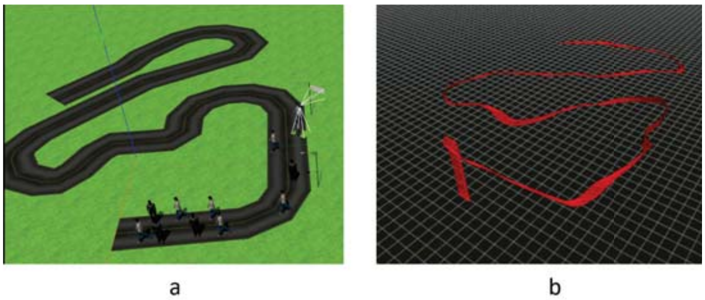

Fig. 7. Drone localization and navigation. (a) map of the road from JDE Robotics. (b) drone surveillance path

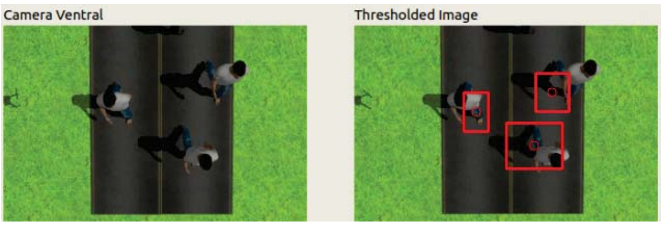

Fig. 8. Detected three people on the road.

TABLE I
PEOPLE DETECTION EVALUATION.

Case	People (Ground Truth)	People Detected (Hit)	Mis
1	2	2	0
2	3	3	0
3	5	4	1
4	7	6	1

C. Real World Person Localization

After the person is detected on ventral camera in Figure 12 we can calculate the location of person in second and fourth quadrant so we can write [x, y, width, height] as [-66, 38, 57, 59] and [49, -1, 72, 62]. Hence, $area_{BB_{drone}}$ = 3363 and $area_{BB_{drone}}$ = 4464 respectively.

Fig. 9. Width and height of detected person bounding box.

In this research, we assume K value as $0.1 meters/pixel^2$ for person in frame and we calculate dx and dy using Equation 3 and Equation 4 we get $dx_{calibrated}$ = 6.6 meters $dx_{calibrated}$ = 3.8 meters for person in second quadrant and $dx_{calibrated}$ = 4.9 meters $dx_{calibrated}$ = 0.1 meters for person in fourth quadrant.

Then, $ds_{calibrated}$ can be computed and we get the distance between person measured from the head to drone is 12.8 meters in second quadrant and 10.7 in fourth quadrant. We also compute calibrated distance between person dp which is 4.8 meters.

D. Social Distancing Violation

Social distancing violation warning is active based on distance between detected people. The green bounding box indicates that the distance between objects meets the social distancing requirements while red bounding box for social distancing violation. Then, the drone tell the global position of the violator to the supervisor. Figure 10 and figure 11 shows how drone monitoring people on the road. The left side of figure is simulation point of view from raw ventral camera. Figure 10 shows drone identify people that obey social distancing. While, in figure 11 some people just walking to close with each other so it categories as social distancing violation.

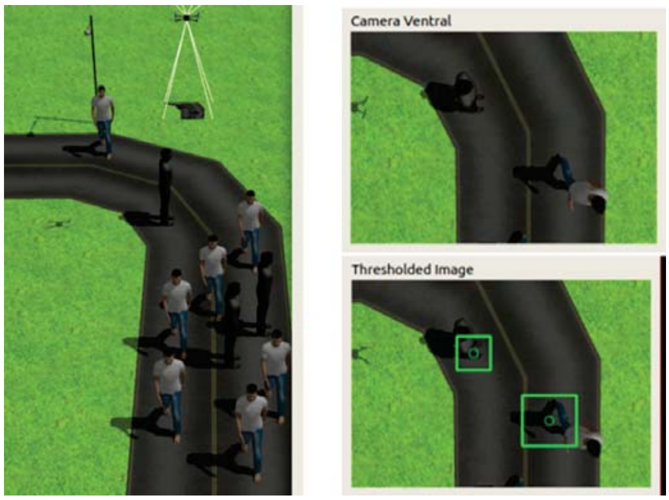

Fig. 10. People obey social distancing on the road.

In figure 12 (a) and (b), drone also can measure social distancing and give marker for social distancing violation in the sidewalk.

E. Crowd Detection

Social Distancing system also has ability to identify crowd. Drone proceed the number and distance of detected people then marking the crowd. Figure 13 displays crowd detection result. We also measure the result in several cases. Table II shows that the proposed method successfully detect the crowd where just mis one crowd in the last case.

IV. CONCLUSION

The design of the Covid-19 Social Distancing Surveillance system is successfully implemented for the first stage in a simulation environment. We use IRIS PX4 as a surveillance agent that has two camera namely ventral and frontal. Data

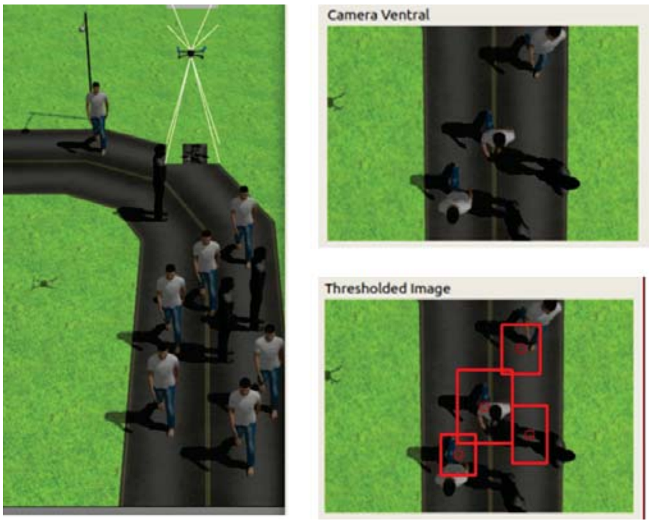

Fig. 11. People violate social distancing on the road.

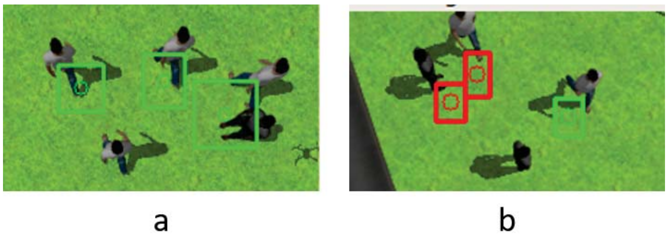

Fig. 12. (a)People obey social distancing on the sidewalk. (b)People violate social distancing on the sidewalk.

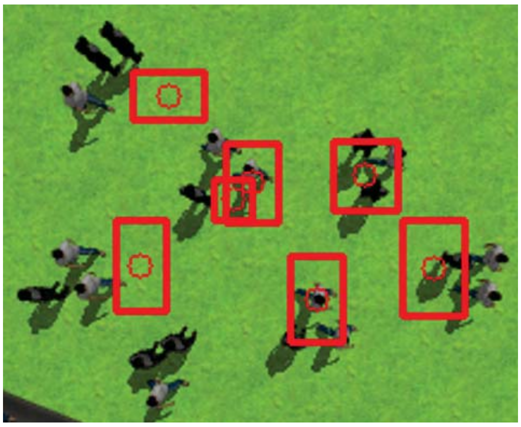

Fig. 13. Drone can detect six over seven crowd.

TABLE II
CROWD DETECTION EVALUATION.

Case	Number of Crowd (Ground Truth)	Crowd Detected (Hit)	Mis
1	2	2	0
2	3	3	0
3	4	4	0
4	5	5	0
5	7	6	1

from the camera is used for road segmentation and navigation. The drone is embed with people and crowd detection algorithm based on fine-tune detection method YOLOv3-tiny. The system also calculate the distance between people and generates an early warning for social distancing violation. The experiment obtained good accuracy results is about 90% both for people and crowd detection. For future work, we have to implement our design and methodology in the real drone. We also can equipped drones with a thermal sensors so drones can identify Covid-19 inspection. We are going to add simultaneous localization and mapping algorithms if drone explore new areas.

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