Roaming “Nagger”

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***Abstract*—COVID-19 is an infectious disease which can spread through respiratory droplets and occasionally airborne method. As the economic sector began to open, places like restaurants and shopping malls are able to open with strict Standard Operating Procedure (SOP) guidelines, such as setting the maximum number of people who are inside a premise, practicing social distancing and mask wearing measures. However, as the situation gets better, we as citizens tend to forget about the importance of social distancing and mask wearing practice. Thus, this project aims to design and develop a roaming “nagger” which produces nagging message when it detects someone who is not practicing social distancing and/or mask wearing measures. By doing so, the spread of the COVID-19 in community can be curbed and controlled, thus breaking the chain of COVID-19 infection. The roaming “nagger” is capable of navigates itself by detecting lines on the floor, wall sensing and also manual navigation which user can control the robot movement remotely. It is also capable of capture real-time video where it is sent from the vision systems to the user’s PC. In this project, a conceptual design is developed using SolidWorks, where the height of the design reaches slightly above knee height.**

I. Introduction

As of June 2021, COVID-19 has been affecting almost every countries in the world, including some territories. Some of the countries with more than 1 million cases are India, USA, Brazil, and Russia, with a handful of countries with 7-digit cases being listed behind. With the continuous ongoing occurrence of COVID-19 cases in Malaysia, most of the states experienced a surge in cases, particularly in most of the Sabah districts and in West Malaysia. As the number of active cases increase exponentially in Malaysia, hygienic practice and social distancing has become the number 1 safety precaution, in order to reduce the spread of the virus.

With the current condition, we as Malaysian citizens might need to adapt to a new norm in the next 1-2 years or possibly more. As for other countries which are severely hit by COVID-19, the time taken to return to a normal life is even longer.

This research project aims to increase the people’s awareness of abiding SOP by following social distancing measures and face mask wearing practice by reminding them using nagging messages/phrases.

A. Project Aim

To design and develop a user-friendly and cost-effective roaming robot which roams around an indoor area and nagging citizens who do not abide by SOP such as mask wearing or social distancing.

B. Objectives

1. To implement the image processing algorithm to detect the absence of mask wearing/social distancing from citizens.
2. To produce nagging message from the speaker to the citizens who do not abide by the Standard Operating Procedures (SOP).
3. To increase the security of the roaming “nagger” by implementing an anti-theft system to prevent the robot from being carried away or stolen by any unauthorized person.
4. To implement sensor for the robot to detect obstacles from the front and also the side when the robot navigates.

C. Research Questions

1. What type of sensors are suitable and effective towards path navigation and obstacle detection?
2. What are the most suitable image processing algorithms for mask wearing or social distancing?

D. Project Scope

This project consists of 4 main sections, which is mechanical (robot chassis design), electronics (circuit and sensor implementation), programming (robot movement and speaker implementation) and computer vision (detection of social distancing and mask wearing using vision-based camera). As for the software aspects, computer vision is to be integrated with programming, the real-time video captured by the camera will be transmitted via Bluetooth/ Wi-Fi to the user in a remote area for monitoring purpose. A speaker will be used together with the camera for the nagging purpose. For path navigation wise, the robot will implement sensors attached on itself, in order for it to navigate itself. This project covers obstacle detection such as human motion in front of the robot and security implementations.

E. Significance

With the continuous spike of COVID-19 cases in Malaysia and all across the globe, vaccination rollouts are carried out by many countries in order to bring down the risk of infection of a very much lower level. However, with the mutation of new COVID-19 variants which is currently spreading rapidly to many countries from its originated countries, the current vaccines may not fully control the COVID-19 cases. Countries like China, Australia, and New Zealand managed to flatten their COVID-19 curves without replying only on vaccines. Instead, the government implements mask-wearing and strict measures in order to avoid any unnecessary gatherings which can potentially spread virus from one to another. The prototype designed and developed could be used by the authorized personnel to monitor whether the citizens abide by SOP. Should there be any citizens who refuse to obey the nagging message produced when he/she does not comply by the SOP, the authorities can be able to penalize the citizens who violate the SOP whenever in public places. The live stream of the situation can be remotely accessed by the person in charge so that the real-life situation can be observed. With the system in place, the risk of getting exposed by COVID-19 can be reduced as gatherings and the absence of mask wearing inside an indoor place can be very risky, and it could be even worse as time goes by. Therefore, the roaming "nagger" serves as a reminder to those who tend to forget about the importance of wearing mask and social distancing.

II. LITERATURE REVIEW

A. Effects of COVID-19 on Various Aspects

COVID-19 is a virus which is transmitted via respiratory droplets and through airborne. Since the beginning of COVID-19 pandemic, countries around the world has start researching on how to tackle this virus pandemic and most importantly developing vaccine for COVID-19. Due to lockdowns implemented by governments, COVID-19 does have a big impact on the world economy. Many small-scaled business are forced to close down due to lack of demand from customers. Companies such as pharmaceutical and medicine firms have advantage during this pandemic as the demand for PPE and face masks balloons up. However, citizens were told by health experts that abiding SOP is the main key to curb the spread of this disease, they are advised to wear masks and practice social distancing whenever in public places. As of 26th May 2021, total COVID-19 cases has reached 168 million cases worldwide, and the death toll is nearly 3.5 million, with the worst-hit countries such as India, USA, and Brazil, where the total cases exceed more than 10 million. Some of the countries which has successfully tackle the COVID-19 pandemic includes China, Australia, and New Zealand, which they have managed to flatten the COVID-19 curve right before vaccines have been developed completely. This shows that rule obeying and discipline are the main keys to stop the spread of virus. Figure 1 below shows the total number of COVID-19 cases worldwide as of 26th May 2021.

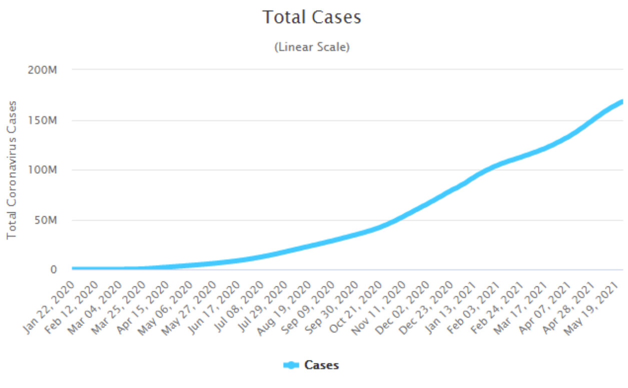

Figure 1: Total Number of Cases Worldwide as of 26th May 2021 (Source: Worldometers) [1]

B. Path Navigation

1) SLAM Algorithm using LIDAR

LIDAR is the acronym for Light Detection and Ranging. It is a remote sensing method which uses light as the emitter to measure distance in the form of laser, and it can generate 3-D information about its surroundings (Figure 2). For example, in a public indoor area, when the light pulse emitted by the LIDAR device hits a target (people, wall, or obstacles), it will bounce back and return to the LIDAR sensor. The distance can be approximated accurately by considering the time taken for the light to be emitted out and return back. Typically, a LIDAR sensor is mounted on a rotating platform stand which can be able to capture many readings around a 360-degree sweep. The maximum sampling rate of the device is around 1000 samples per second, hence it is able to capture sufficient data. In other terms, LIDAR implements the algorithm of SLAM (Simultaneous Localization and Mapping). For SLAM method, a mobile robot will perform an estimation of map in an environment while simultaneously localizing itself with respect to the map estimated. [2]

[3] Unlike vision-based SLAM algorithm, laser-based SLAM algorithm is more capable of performing indoor mapping in a more accurate way. It implements LIDAR which acts as a range finders to do laser scanning in 2D, it provides high resolution real-time images with high sampling rates, which contributes to a smoother image captured. Figure 8 shows the process of indoor path navigation and mapping using LIDAR method in Figure 2 below:

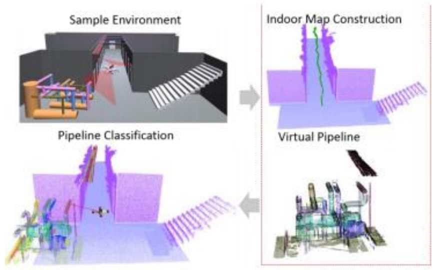

Figure 2: Overall Process of Indoor Path Navigation using LIDAR (Ajay Kumar, G, 2016) [3]

2) Line Tracking and Detection

Line Following Robot is one of the most important yet common navigation for robot to roam around an area. On the floor, either black or white lines are drawn. For the sensors, IR Sensor are used to detect the line on the floor. When IR Transmitter emits ray onto a surface, the reflected ray will be bounced back and return to the IR Receiver. The amount of rays reflected back depends on the contrast of the line, which is shown in Figure 3.

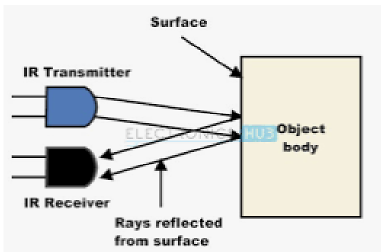

Figure 3: Illustration of how IR Sensor works

According to Chowdhury [4], a line follower robot can be implemented using 4 pairs of sensors attached adjacent to each other with a suitable distance between it. By implementing this number of sensors, the robot can able to detect T-junctions and 90 degrees bends. The robot will then roam around the area with the guided line located between the sensors. There are a few scenarios where the robot will encounter. Figure 16 shows the normal condition when the robot moves in a straight direction. Hence, all the four IR sensors will detect the black region, and both motors will run at full speed.

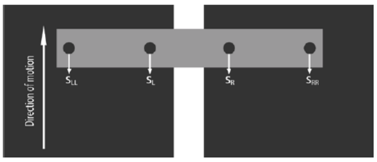

Figure 4: Top View of how the setup of Line Follower Robot (Chowdhury, N, 2017) [4]

When the robot starts moving, both sensors will detect the outer path which is not the black line. When there is a change in direction of the line (e.g. turning to left/right), one of the sensors will detect the lines on the floor because the robot moves in a straight line while the lines are changing direction. In the case where either the middle left or right sensor detects the line path, the robot needs to turn to the opposite direction until all the sensors are not detecting the black line. This can be illustrated in Figures 5 and 6.

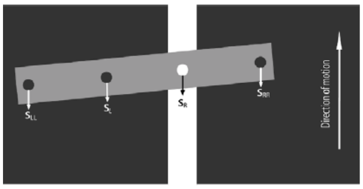

Figure 5: Scenario when the robot needs to rotate to the right. (Chowdhury, N, 2017) [4]

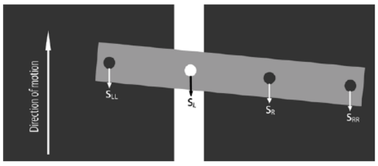

Figure 6: Scenario when the robot needs to rotate to the left. (Chowdhury, N, 2017) [4]

C. Vision Systems

Long before machine and cameras are invented, human used the traditional method in inspecting an object or a part by using their own eye. Despite the fact that human eye is able to execute a task better than machine in some cases, they tend to get exhausted after a series of non-stop routine-based task, such as carry out object inspection. This applies the same in detecting face mask and social distancing in public areas, where authorities are able to spot if anyone did not wear a mask or not practising social distancing immediately. However, due to current COVID-19 pandemic, monitoring of such conditions can be risky, especially if the citizen who is not wearing mask/following social distancing is exposed to the virus but showing no symptoms. Therefore, monitoring of such scenario by a roaming robot is a better and much safer option. Figure 14 shows how an industrial vision system works. In order to interface a vision system, a computer is needed to process the input images by integrating image processing and software into it.

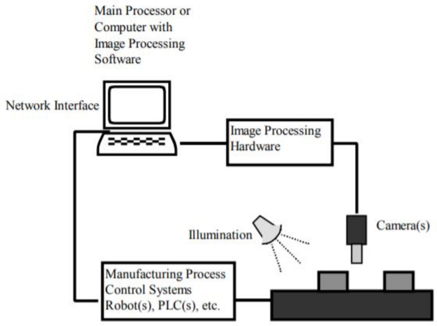

Figure 7: Inspection System used in Industrial Robot [5]

Machine vision is a subset of artificial intelligence where it integrates image processing and automation together to perform object detection in an automated manner. Machine vision can be either 1-D, 2D or 3D vision systems. In this section, 2D vision systems and 3D vision systems will be discussed, as well as their uses in industry, advantages and drawbacks.

1. 2D Vision Systems (2D Scanning)

2D vision systems are vision system which analysis an image directly perpendicular from the image base. In other words, when performing 2D image analysing, the horizontal and vertical coordinates, as well as the orientation of the object will be known. 2D vision systems are the most commonly used inspection cameras that carry out area scans. In this vision system, a camera will be installed above the position or its capturing view line is perpendicular to the plane of the object. As shown in Figure below, the object is positioned in 3 coordinate axis, which are x, y and z-axis.

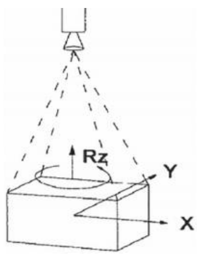

Figure 8: Schematic of how 2D Vision System Works [6]

2D vision system provides area scans that work well for discrete parts [7], it is able to analyse images with various resolutions. However, this type of vision system does have limitations. The accuracy of the image detection can be affected if changes in ambient conditions or artificial lighting occurs. Therefore, 2D vision system is somehow light-sensitive. Another issue is that 2D machine cannot handle additional height difference if the image is placed flat on the ground. Therefore, 2D vision system is not suitable to be used in a pick and place application or detection of any image involving more than 2 axis.

2. 3D Vision Systems (3D Scanning)

Unlike 2D vision system, 3D vision system provides 6 degree of freedoms instead of just 3. 3D vision system can be explained using analogy of our human eyes (2 eyes). When the object is being positioned, the 3D vision system utilizes 2 cameras with different orientation angle to capture the image simultaneously [8]. Due to its 6 degree of freedom positioning system, it is able to provide x, y, and z-axis parameter with the rotational information in these 3 respective axis, as shown in Figure 9 below:

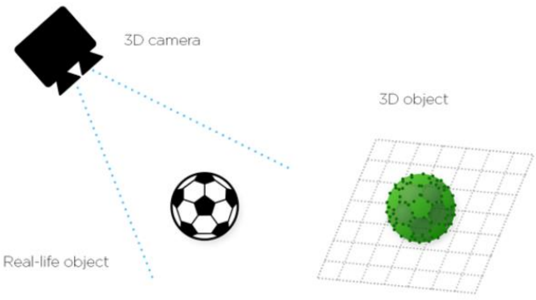

Figure 9: Illustration of how the Image is projected on the plane using 3D-vision system [8]

3D vision system possesses several advantages compared to 2D vision system. First and foremost, it has a wider range of usage due to the additional orientation that can be detected. By utilising 3D vision system, more than one object can be analysed at the same time by using reference coordinate system [8]. Hence, it can be used in a more complex and uncontrolled environments.

On the other hand, 3D vision system does have some limitations as well. Due to its nature of image processing method, 3D vision system takes more time to execute the task [8], and it also consume more power as it is very software intensive. However, since 3D vision system has wider range of parameter detection due to the 6 degree of freedom positioning, 3D vision system is more recommended in executing object detection, particularly when the image is a live stream video that consists of objects moving around.

III. METHODOLOGY

A. Overview

The roaming "nagger" will be powered up by a rechargeable battery pack of 12V which is capable of powering the Raspberry Pi 4B for several hours up to half a day. When the robot is placed at the initial starting position, user can select the type of path navigation that the robot should go for based on the places, then it will start to roam around an indoor area and nags at citizens who do not abide by SOP. On the camera side, indication will be marked on the video to show whether citizens are wearing mask by creating a red frame surrounding a person's face if mask is absent, thus triggering the nagging function. For social distancing, a larger rectangular box will be used to surround the person in the video and the robot will start nagging at citizens if two or more of the rectangular frame boxes are detected very close to each other.

On the other hand, an ultrasonic sensor will be attached at the robot base to detect any sudden change of distance between the robot base and the ground, so that the robot is able to tell that whether someone has lifted up the robot or attempted to steal the robot. A loud buzzer will be triggered if someone attempts to steal the robot, thus alerting people surrounding about what have happened.

B. Isometric View of Prototype

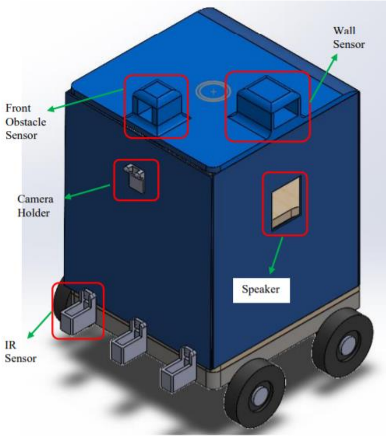

Figure 10: Isometric View of Robot drawn in SolidWorks

From Figure 4, the prototype is measured 30cm x 30cm for its base dimension, its height is measured at 50 cm, excluding the ultrasonic sensors placed on top.

C. Block Diagram and Circuit Diagram

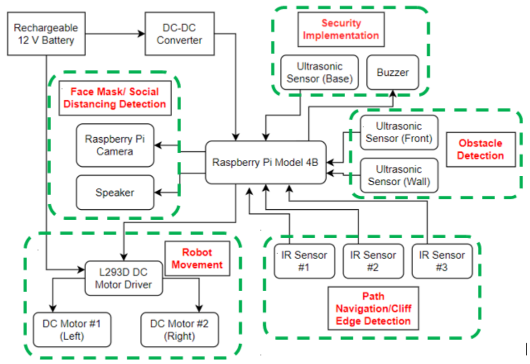

Figure 11: Block Diagram

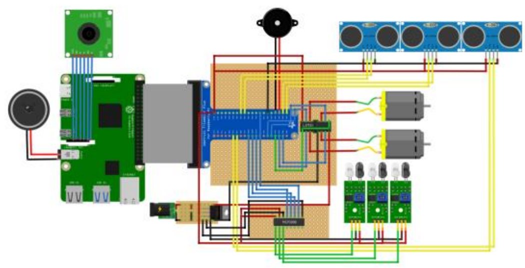

Figure 12: Circuit Diagram of Roaming "Nagger"

Based on the block diagram, the project is divided into 4 main categories, which are path navigation, robot movement, security implementation, and also implementation of computer vision to detect face mask/social distancing. For the power supply, the 12V is connected to the L293 DC motor driver and the 5V output is connected to the Raspberry Pi 4B input port.

In this project, 3 ultrasonic sensors will be used, each sensor is responsible for wall detection, front obstacle detection, and security implementation respectively.

D. Features

1. Security Implementation

When the robot is moving, the distance between the ultrasonic sensor at the robot base and the ground will be consistently updated throughout the process. When the distance above 20cm has been detected by the ultrasonic sensor, the DC motors will stop and the buzzer will be triggered. The program will prompt user to enter the default password which is fixed by the program. If the password entered matches the default password, then the alarm will be disabled. However, the robot will not start moving until user reactivate the robot by entering ‘1’ to continue, so that the robot can resume its operation, as shown in Figure 10 below:

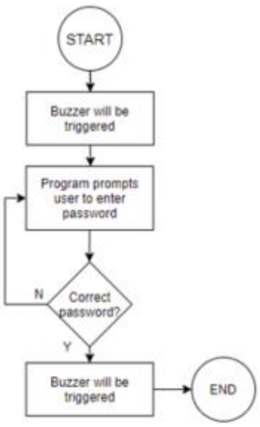

Figure 13: Flowchart of Security Implementation

2. Path Navigation and Obstacle Detection

Normally free path navigation will be used for the robot to moves freely around an area without following any indicators or markings. For free navigation, the ultrasonic sensors at the front and side of the robot will be used to detect obstacle. The robot will turn 90 degree to the left/right side when an obstacle is detected in front.

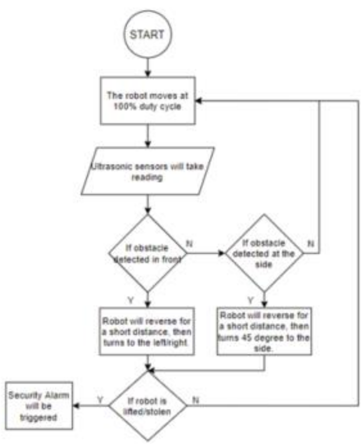

Figure 14: Flowchart for Free Path Navigation

3. Cliff Edge Detection

The 3 IR sensors installed in front of the robot has 2 functionalities, which are either navigate path by tracking line on the ground. The 2nd function of the IR sensors is to detect any cliff edge in front of the robot, in order to reduce the risk of robot falling down from an elevated surface or a cliff. Since these sensors will be installed at a distance in front of the wheels, therefore it is able to detect any sudden change in their analogue input value.

4. Face Mask/Social Distancing Detection

For the face mask detection, an AI training model will be trained so that the camera is able to identify the person wearing a mask or not. In order to train the AI data, nearly 1000 sample images for each category(with mask and without mask) are needed for the AI model to be trained. When the camera senses the presence of mask covering the person’s nose and mouth, it will indicate as wearing mask. However, if a person does not wear mask or pulls the mask down to his/her chin, the speaker will produce nagging message to the person, reminding him/her of wearing mask in public places.

IV. RESULTS

A. Finalised Prototype

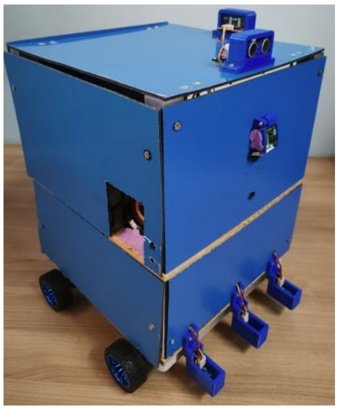

Figure 14: Isometric View of the Assembled Prototype

B. Testing of IR Sensors in Different Conditions

1) Effects of Placement of sensors from different height on the IR sensor analogue input

Table 1 shows the input voltage obtained from the IR sensor when placed at different height from the ground, with the graph of sensor voltage vs height plotted in Figure 16.

Table 1: Tabulation of data obtained for different heights

	Input IR Sensor Voltage (V)		
Height (cm)	**Black/Dark Grey surface**	**White surface**	**Yellowish surface**
2	2.21	0.447	0.363
3	2.11	0.385	0.341
4	1.31	2.21	2.06
5	1.62	2.29	2.86

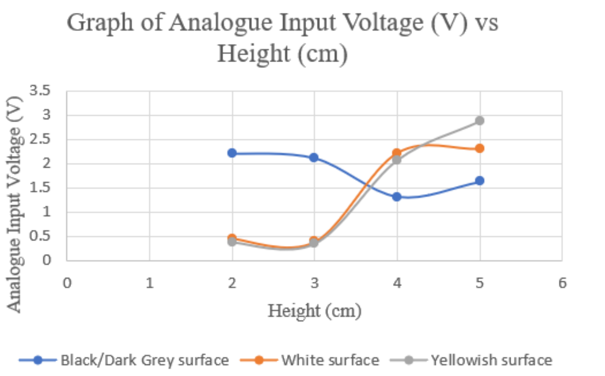

Figure 15:Graph of Analogue Input Voltage of IR sensor vs Height from the ground

2) Effects of Placement of sensors from different height on the IR sensor analogue input

Figures 14, 15, and 16 below show the graph of IR sensor value vs the types of surface at a fixed height of 2.5 cm from the ground.

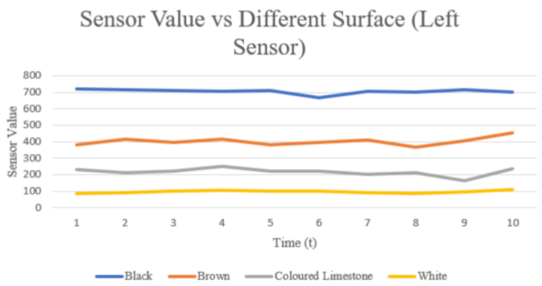

Figure 16: Graph of IR sensor value vs different types of surface (left sensor)

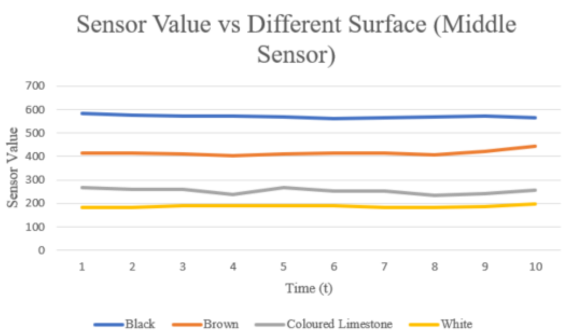

Figure 17: Graph of IR sensor value vs different types of surface (middle sensor)

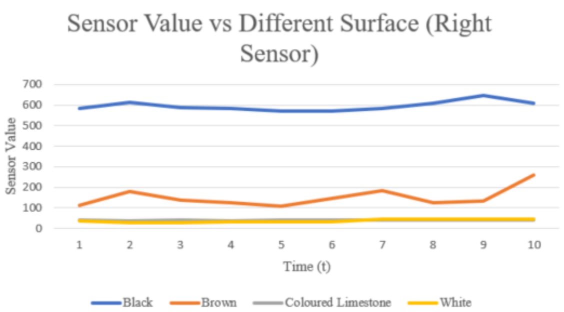

Figure 18: Graph of IR sensor value vs different types of surface (right sensor)

Based on the 3 figures above, it is shown that white and coloured limestone surface has the lowest IR sensor input value, whereas black surfaces result in the highest IR sensor input value.

As a result, choosing different coloured tapes is crucial for accurate path navigation. By doing so, the sensor is able to tell the difference between the floor and the line. In any situations, white tape should not be paired together with the floor which has similar colour as the coloured limestone surface.

3) Camera View for Face Mask

Figure 20: Results (Mask is Present)

Figure 21: Results (Without Mask)

In Figure 17 and 18, when the camera detects the person wearing a mask which covers both nose and mouth, it will surround the face with a green box, indicating the presence of mask. For the mask to be undetected, the person is either not wearing mask or pulls down his/her mask down to the chin. In order for detection of face mask, the range of detectable distance is between 1 m to 1.8 m .

V. CONCLUSION

This project is considered as a sustainable and reliable product as it handles indoor areas which can be of high risk, especially when there are potential COVID-19 infections within the indoor area. Most of the features are able to work properly with further calibrations still required. For the future work, it includes creating of web application for the video to be streamed online, as well as implementing both the mask and social distancing detection.

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