Swinburne University of Technology

Sarawak Campus

Faculty of Engineering, Computing and Science

Workbook

Bachelor of Engineering (Hons)

(Robotics & Mechatronics)

Chuah Ding Ken (101218820)

Semester 1, 2021

Table of Contents

Lists of Tables

Lists of Figures

Module 7

7.1 – Identifying an Academic Argument

Debate: Using ultrasonic and IR sensors is the most effective way in navigate the robot around an indoor area.

Opposing View 1: Using these 2 sensors doesn't allow the robot to have the memory to remember the path.

Opposing View 2: There will be some blind spots when the robot navigates around, as ultrasonic sensor does not have a very wide range of detection.

Supporting Side:

Ultrasonic sensors are effective in detecting an obstacle at a greater distance compared to any other distance measuring sensors such as IR sensors and PIR sensors. Therefore, it is able to reduce the rate of collision between the robot and the obstacle due to its greater range of detection. If one or more ultrasonic sensors are placed on the side of the robot, the robot will avoid some of its nearby obstacle at the side. One of the example of home appliance which mimics such placement of sensors is the smart robot cleaner, which is typically a small cylindrical robot of height around 10 cm. There are wall sensors built on the side of the robot, so that the robot is able to follow along the wall. Similarly, if the ultrasonic sensors are placed at the side, the robot is also able to follow along the wall as a reference point. Therefore, an ultrasonic sensor can be placed on either side of the robot so that the robot can choose which side of the wall as a reference point (whether the robot should keep left or keep right when moving). Additionally, ultrasonic sensors are suitable to be used in a place where crowds are expected, as people may move around more frequently.

Opposing Side:

One of the most advanced method of navigation is the SLAM method. This method is used by the LIDAR sensor. LIDAR sensor scans an area with a complete 360-degree of view in order to detect any obstacle surrounding it. After finishing the scanning process, the robot can be programmed to move automatically from one place to another , even there is an obstacle placed suddenly in the middle of its path. Therefore, LIDAR can be considered as one of the most accurate device to aid the robot in path navigation. However, due to the limitation that LIDAR sensors are expensive which greatly exceeds the project budget. Therefore, plan B which is the alternative solution is used for the path navigation.

7.2 – Creating Your Own Scholarly Argument

Claim: Path navigation can be effectively implemented using ultrasonic sensors.

Supporting Points:

1. Places of implementation

Ultrasonic sensor emits sound waves which reflects back when it hits the obstacle. Due to the fact that indoor areas such as corridors inside a shopping mall has limited space around. Therefore, fast moving object are extremely rare in such place, therefore ultrasonic sensors are suitable to be implemented at such area as they do not disrupt other areas when scanning an area. For LIDAR sensors, if the human traffic surrounding is quite busy, the LIDAR need to constantly scan the surrounding before planning its route. Therefore, in places where more human traffic is expected, ultrasonic sensor is a better option because closer ranges of detection will be expected from ultrasonic sensor, making it ideal for this situation.

2. Impacts on Health and Complexity

LIDAR sensor which has potential harmful effects to human eye, especially those more advanced LIDAR sensor device which can emit stronger pulse which is detrimental to human eye. Therefore, LIDAR sensor must be equipped with a safety guard above the sensor. On the other hand, the sound waves emitted by the ultrasonic sensor has negligible effects on human as the sensor system is properly mitigated. Therefore, ultrasonic sensor does not require any external system to isolate the sound waves.

3. Low-cost implementation

Compared to LIDAR sensor, ultrasonic is by right the most economical distance measuring sensors to be used due to its low-cost implementation. LIDAR sensors are generally implemented in industrial grade applications, such as safety systems in machinery and mapping of geographical land in 3-dimensional.

Module 8

8.1 – Structuring Your Arguments in a Scholarly Article

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.

Objectives:

1. To evaluate the effectiveness between ultrasonic sensors and LIDAR sensor in path navigation and obstacle detection of the robot.

2. To study and implement the suitable image processing algorithms to detect the absence of mask wearing and social distancing of citizens.

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 test the functionalities of the algorithms implemented.

Research Questions:

1. What type of sensors are suitable and effective towards path navigation and obstacle detection?

2. What is the most suitable image processing algorithm for mask wearing or social distancing detection?

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 authorised 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 penalise 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 whose who tend to forget about the importance of wearing mask and social distancing.

Overview:

The roaming “nagger” will be powered up by a rechargeable battery pack of 12 V 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.

Outcome:

All the research questions are addressed and is able to be answered accordingly. The mechanical, electronic, and the software part is successfully integrated together so that the roaming “nagger” can perform the required tasks. As for the mechanical side, a robot chassis has been designed and built out using stronger but lighter materials as the chassis shell. For example, aluminium composite panel is used as the robot outer chassis to cover up the internal wirings and peripherals inside the robot. Some of the 3D-printed parts are used to hold the sensors in place so that the sensor can carry out its specific function, particularly in path navigation. As for the camera interface, the image processing algorithms are developed to detect the absence of mask wearing/social distancing at a certain distance away from the robot. With the system implemented, security officers do not have to jeopardize themselves by monitoring whether citizens abide by SOP, as this would be considered as a high-risk task as the security officers might be in close contact with any citizens of having potential exposure of COVID-19 infection. Therefore, monitoring of citizens abiding by SOP can be carried out without the risk of exposing to the COVID-19.

8.2 Structuring Your Research Paper

-Please refer to the research paper draft attached on the next page:

Roaming “Nagger”

Ding Ken Chuah and Dr. Almon Chai

Faculty of Engineering, Computing, and Science,
Swinburne University of Technology Sarawak Campus
Jalan Simpang Tiga, 93350, Kuching, Sarawak, Malaysia
Email: achai@swinburne.edu.my

***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.**

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.

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.

Objectives

5. To evaluate the effectiveness between ultrasonic sensors and LIDAR sensor in path navigation and obstacle detection of the robot.
6. To study and implement the suitable image processing algorithms to detect the absence of mask wearing and social distancing of citizens.
7. 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.
8. To test the functionalities of the algorithms implemented.

Research Questions

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

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.

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.

LITERATURE REVIEW

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.

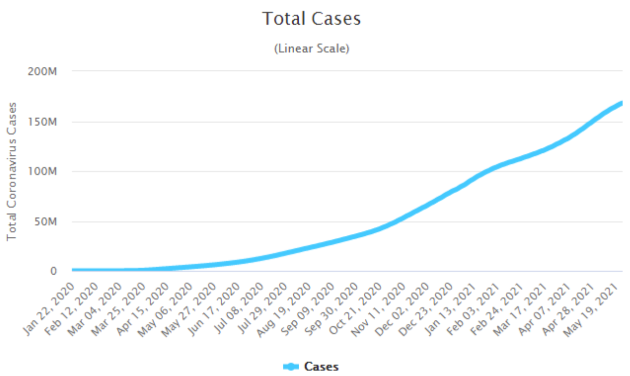


Figure 1: Total Number of Cases Worldwide as of 26th May 2021 (Source: Worldometers) [1]

Path Navigation

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:

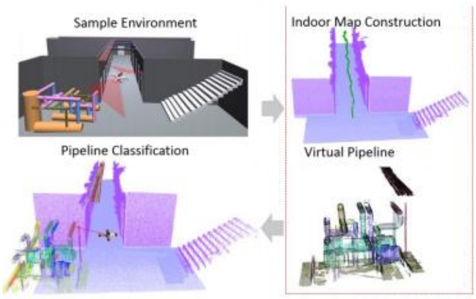


Figure 2: Overall Process of Indoor Path Navigation using LIDAR (Ajay Kumar, G, 2016) [3]

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.

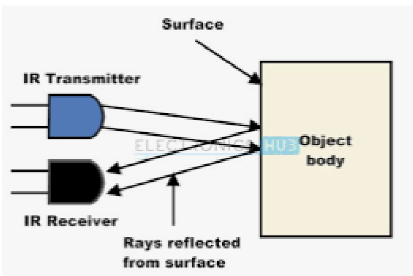


Figure 3: Illustration of how IR Sensor works

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.

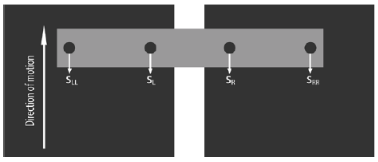


Figure 4: Top View of how the setup of Line Follower Robot (Chowdhury, N, 2017) [4]

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.

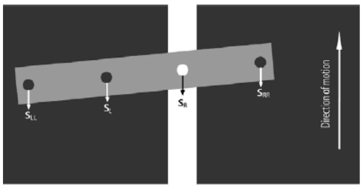


Figure 5: Scenario when the robot needs to rotate to the right. (Chowdhury, N, 2017) [4]

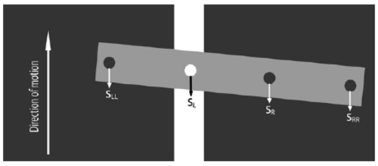


Figure 6: Scenario when the robot needs to rotate to the left. (Chowdhury, N, 2017) [4]

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.

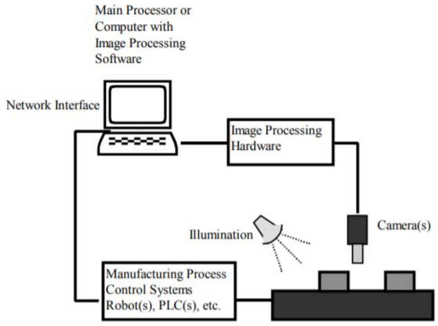


Figure 7: Inspection System used in Industrial Robot [5]

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.

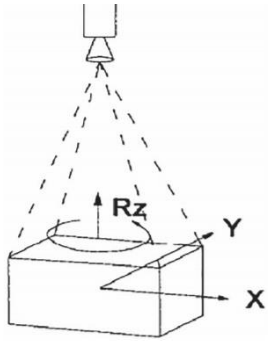


Figure 8: Schematic of how 2D Vision System Works [6]

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:

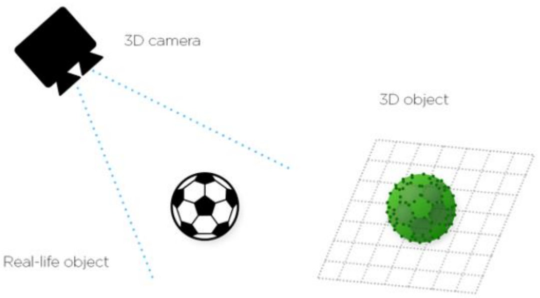


Figure 9: Illustration of how the Image is projected on the plane using 3D-vision system [8]

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.

Methodology

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.

Isometric View of Prototype

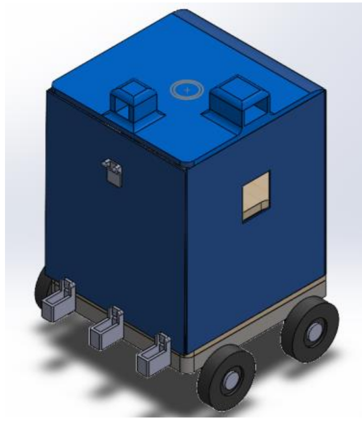


Figure 10: Isometric View of Robot drawn in SolidWorks

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.

Block Diagram and Circuit Diagram

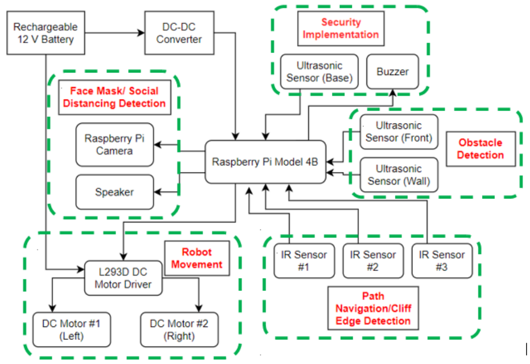


Figure 11: Block Diagram

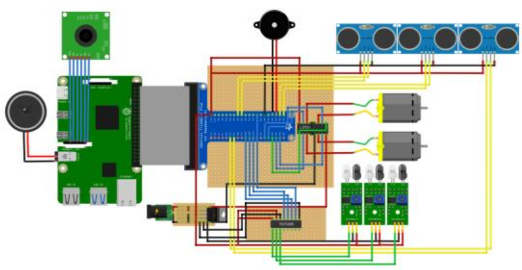


Figure 12: Circuit Diagram of Roaming "Nagger"

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.

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:

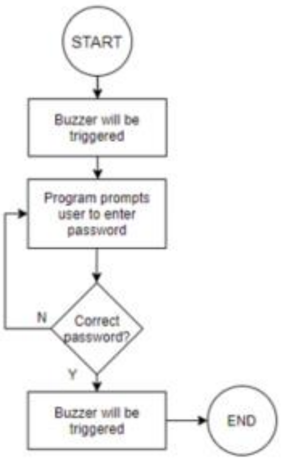


Figure 13: Flowchart for Security Implementation

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.

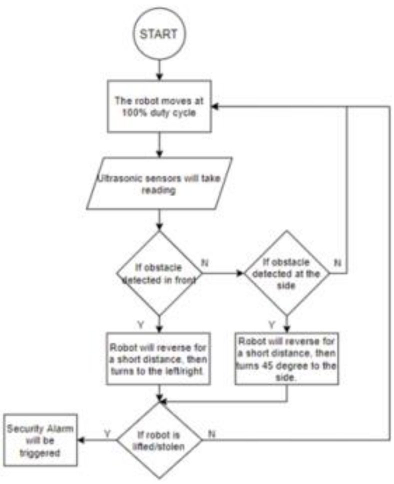


Figure 14: Flowchart for Free Path Navigation

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.

Results

Finalised Prototype

Figure 15: Isometric View of the Assembled Prototype

Testing of IR Sensors in Different Conditions

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

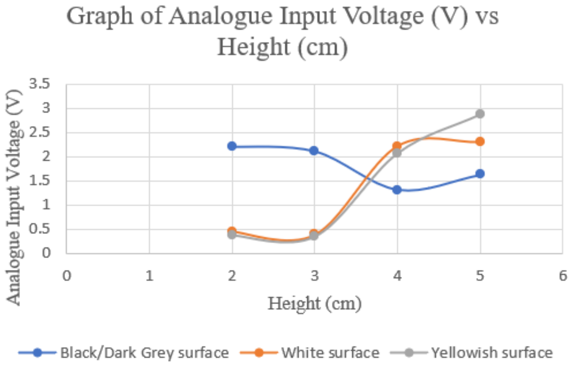


Figure 16: Graph of Analogue Input Voltage of IR sensor vs Height from the ground

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.

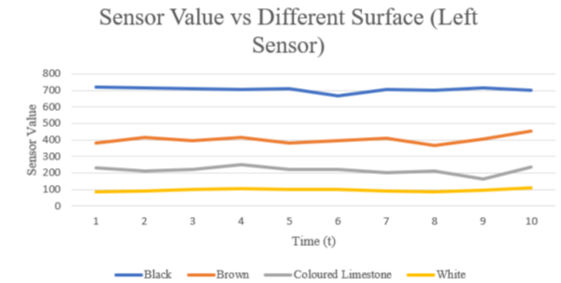


Figure 17: Graph of IR sensor value vs different types of surface (left sensor)

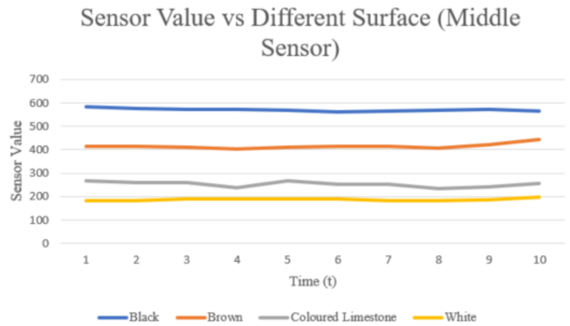


Figure 18: Graph of IR sensor value vs different types of surface (middle sensor)

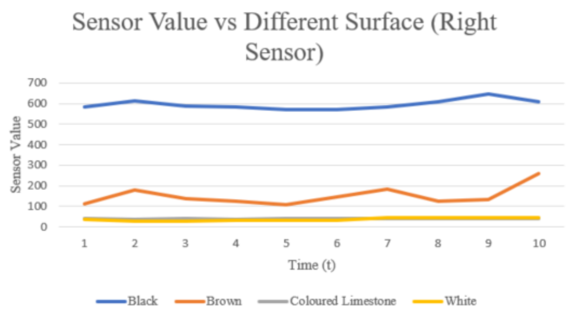


Figure 19: Graph of IR sensor value vs different types of surface (right sensor)

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.

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 .

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.

References

[1] Worldometers. (2021). *Coronavirus* [Online]. Available: https://www.worldometers.info/coronavirus/

[2] Clemens, J, Reineking, T & Kluth, T 2016, "An evidential approach to SLAM, path planning, and active exploration", *International Journal of Approximate Reasoning*, vol. 73, pp. 1-26.

[3] Kumar, G, Patil, A, Patil, R, Park, S & Chai, Y 2017, "A LiDAR and IMU Integrated Indoor Navigation System for UAVs and Its Application in Real-Time Pipeline Classification", *Sensors*, vol. 17, no. 6, p. 1268.

[4] Chowdhury, N, Khushi, D & Rashid, M 2017, “Algorithm for Line Follower Robots to Follow Critical Paths with Minimum Number of Sensors”, *International Journal of Computer (IJC)*, vol. 24, no. 1, pp. 13-22

[5] Malamas, E, Petrakis, E, Zervakis, M, Petit, L & Legat, J 2003, "A survey on industrial vision systems, applications and tools", *Image and Vision Computing*, vol. 21, no. 2, pp. 171-188.

[6] Cui, L 2019, "Complex industrial automation data stream mining algorithm based on random Internet of robotic things", *Automatika*, vol. 60, no. 5, pp. 570-579.

[7] Anon 2021, *Types of machine vision systems*, [Online] <https://www.vision-systems.com/knowledge-zone/article/14040180/types-of-machine-vision-systems#:~:text=2D%20vision%20systems%20provide%20area,for%20most%20machine%20vision%20applications.&text=Camera%20sensors%20in%2010%2C%2020,standard%202D%20product%20lineups%2C%20however.>.

[8] Schumann-Olsen, H 2021, *Why 3D machine vision? What’s wrong with 2D machine vision?*, viewed 3 June, 2021, <https://blog.zivid.com/why-3d-machine-vision-whats-wrong-with-2d-machine-vision>.

Reflective Journal

Professional Engineering Practice/Project Management

A4 Information Management: Demonstrates seeking, using, assessing and managing information

This project involves information gathering which consists of not only the literature review, but most of the information gathered are required to execute the project tasks. From starting till the end, this includes configuring and setting up of Raspberry Pi 4B and integrating vision camera with software so that the prototype performs as expected from the project scopes. Unlike Arduino which can be connected to the laptop, Raspberry Pi 4B requires additional and more complex setup procedures before it can be used to program and control the GPIO and other peripheral interfaces.

At the 1st stage of information gathering, Raspberry Pi 4B can be accessed either SSH of Ethernet cable method. However, due to the absence of Ethernet port in the laptop, SSH will be used for remotely accessing the Raspberry Pi 4B. To do so, the IP address of the Raspberry Pi 4B must be obtained before it can be remotely accessed. However, the IP address of Raspberry Pi 4B can only be obtained if it is connected to a Wi-Fi. Therefore, a monitor, keyboard and a mouse is required to be connected to the Raspberry Pi 4B USB ports. Additionally, the SD card needs to be flashed with a software called NOOBS, which is required to run the Raspberry Pi OS system(called Raspbian OS). After inserting the flashed SD card into the SD card slot, the Raspberry Pi is ready to be initialised and configured. Just like every PCs or laptop, Raspberry Pi 4B requires setting up personal details, such as password and time zone setting, as well as connecting to a Wi-Fi so that the IP address can be obtained, which in turns allows the Raspberry Pi 4B to be accessed remotely.

However, due to the fact that the Raspberry Pi 4B will be placed inside the prototype which is powered up by a battery. Therefore, Raspberry Pi 4B desktop needs to be accessed remotely via VNC Viewer. For VNC Viewer connection, IP address of Raspberry Pi 4B needs to be obtained as well.

At the logbook, I have written a 4-week logbook during the semester break before taking FYP2. This 4-week logbook explains the procedures required to setup a Raspberry Pi 4B, as well as the configurations need to be done to remotely access and interface the GPIO ports. The logbook is basically divided into 4 different sections. The 1st section explains the configuring and setup of Raspberry Pi 4B, the 2nd section explains the mechanical parts required to build the prototype, as well as the procedures of how the prototype is built from using these sourced components. The 3rd section explains the electronic circuit designing, as well as wiring and soldering of the components into vero stripped board. The final section of the logbook details the software and image processing tasks being carried out, as well as testing and calibration of the prototype. Below lists the tasks carried out from the semester break until the end of FYP2:

- Phase 1 (Semester Break)
- Phase 2 (Week 1-3)
- Phase 3 (Week 4-6)
- Phase 4 (Week 7-Tuition Week)

In my opinion, I believe that splitting the logbook into several sections allows reader to look through the details of each tasks carried out by each phase. As logbook is one of the important components for final year research project documentation, it is an evidence that the student has put efforts in carrying out his/her research project.

K5 Practice Context: Discerns and appreciates the societal, environmental and other contextual factors affecting professional engineering practice.

When conducting literature review of this research, I realised that the lists of roaming robot which implements vision systems in the market. After gathering a few available news articles of the available robots in the market, analysis will be carried out by first understand what is the tasks carried out by the particular robot, then followed by the advantages and disadvantages of each robot. The advantages and disadvantages of the robots will be tabulated in a table for them to be reviewed.

Based on the literature review, the solution that I have proposed is a roaming robot which is able to detect the presence of social distancing and mask wearing using computer vision technology. In order to monitor an area remotely the robot is connected to user's PC at other place via Wi-Fi data transmission and VNC Viewer remote access. Hence, monitoring of an area can be done safely without having the person in charge/authorities to jeopardize themselves from the risk of getting COVID-19 infection. Additionally, a security features is proposed which prevents anyone from attempting to steal the roaming robot in an area.

S4 Project Management: Systematically uses engineering methods in conducting and managing project work including finance.

When executing a research project, project planning is very important so that the project can be completed within the timeframe. Project planning involves how the project is being carried out from the start until the end, as well as the materials and components needed to build the project prototype.

Before starting designing the project prototype, material sourcing is needed so that I can finalise the components needed and purchase all of it in one shot. This also allow me to start my project prototype building and assembling earlier, as some orders require additional days due to unforeseen circumstances such as shipment delay or long public holidays. As discussed during FYP1, the materials sourced are based on the finalised conceptual design. When it comes to material sourcing, it can be divided into several parts, which are mechanical component parts, electronic sensors and ICs, Raspberry Pi 4B peripherals, as well as board connectors and power supply.

During FYP2, first the physical prototype of the robot must be built and assembled from the purchased component parts. After finishing the prototype skeleton, the circuit will be designed and soldered into the vero board, followed by connecting the vero boards and the GPIO extension board of Raspberry Pi 4B with connectors. Before soldering, the electronic sensors and devices will be tested on breadboard before soldered into the vero board, so that any defective components or sensors can be identified at earlier stage. After the electrical task has been done, programming will be written and tested on the robot, including integrating the programming into the circuit and the hardware such as Pi Camera and the speaker.

The tasks required to be carried out will be put into Gantt chart, whereby the duration and the date of the tasks to be done are defined. As for the finance part, due to unforeseen circumstances which is COVID-19 pandemic, some of the components such as Raspberry Pi 4B could not be borrowed from the campus. Therefore, some of the expensive components need to be purchased by myself. Therefore, strict budget planning is required so that I won't be overspending too much from the maximum project budget. As a result, I managed to reduce the project budget to be around RM 900 despite it still exceeds the maximum budget provided, which is RM 600.

Professional Issues within the project

K6 Professional Practice: Appreciates the principles of professional engineering practice in a sustainable context

The project is a prototype design project involving building and assembling of a mobile robot called Roaming "Nagger". Since the roaming "nagger" is to be deployed in an indoor public area where many citizens are walking around. Accident may happen such as the collision between the robot and citizens if safety feature is not implemented. To avoid this from happening, sensors are required to be installed to detect human motion in front of the robot.

Additionally, since the robot is powered up by a portable battery pack, the need of a rechargeable 12 V battery pack is required as rechargeable battery can allow the robot to be powered up by the same battery pack over and over again. This prevents the e-waste issue which is caused by the disposal of battery pack when the battery has been used up completely, which contributes to the environmental and sustainability aspect.

Personal Professionalism, Integrity, Ethical Conduct and Professional Accountability in Project Work

A1 Ethics: Values the need for, and demonstrates, ethical conduct and professional accountability.

During the testing and troubleshooting process, it is common that the data obtained is different from the expected outcome during the initial stage, because for some cases expectations and reality are somehow different. As a result, proper troubleshooting of the error occurred is needed.

The error caused by inaccurate and inconsistent data obtained may be due to the sensor placement and insufficient calibration. In some cases, software bug may be one of the cause that the developed solution is not working properly.

With the professional ethical conduct, data analysis and faulty analysis will be performed so that the actual output performs almost the same as the expected output. Each time a troubleshooting or testing has been conducted, a documentation consisting of the findings with detail justification will be carried out and I will notify the supervisor. For example, when the DC motor stops rotating even the program has been initialised, I will turn off the power and test the connectivity between the L293 motor driver and the DC motor, and apparently the L293D is burnt due to wrong chronological order of placing the chip. To prevent the chip from burning, the power must be switched before placing back the IC chip back into the socket.

As a engineering student or an engineer, datasheets are very commonly used because datasheets tell us the specifications present inside the parts such as sensors and DC motors. Before executing the task such as connecting the sensors or any electronic components to the power source, inspecting is required so that no short circuit or electronic ICs are burnt will occur.

Since the project is a research-based project, therefore thorough and sufficient research and literature review needs to be done before starting to carry out the project methodology. Just like Research and Development (R&D) field in industry, most of the tasks carried out were researching on how the project needs to be carried out, before executing the tasks sequentially.

A2 Communication: Demonstrates effective communication to professional and wider audiences including in complex engineering activities.

Throughout the FYRP2, the most commonly used communication medium is through meetings with supervisor regularly. During each meeting, I will present what I have done from last week until now, followed by feedbacks provided by my supervisor. This also ensures that I won't lose track of any progress that I have made. Also, my supervisor will be able to know what I have done so far from week to week. At the end of FYRP2, there will be a final presentation where I am required to present the tasks that I have carried out to the audience.

In FYRP2, there are 3 paperwork documents which I need to prepare. The 1st one is Project report, where I need to document all my literature findings, methodology (Assembling, Wiring and Programming) carried out, as well as any Results and Discussions carried out as well. For the 2nd document, it is called Research Paper. A research paper has similar format as report, the main difference is that research paper is compressed to around 5-6 pages, and it only presents the most crucial and important information to the audience. The 3rd document is a workbook, which comprises of FYP research modules, reflective journal, logbook and supervisor meeting minutes. Logbook serves as an important medium in conveying tasks executed during the project, as it details out the specific tasks carried out in each short period of timeframe.

A5 Professional Self: Demonstrates professionalism and life-long learning

Professionalism is an essential key in engineering context, engineers need to carry out their task with key qualities, which demonstrates engineering competency. For the research project, continuous learning is one of the aspect of engineering competency. As technology is evolving all the time, technical knowledge and skills are to be updated based on the new trend of technology.

One of the example of life-long learning skills is the literature review. In the research project, literature review is conducted and written in a document file. From time to time, research articles are published to the Internet in credible and reliable sources. Books and journal articles are examples of credible sources, which guides the documentation of literature review.

Another great example that can be seen in FYRP2 is the software artificial intelligence implementation. Since AI is required for face mask detection, I spent nearly 1 week try to understand how the AI model is trained using gradient descent method. I also tune around with the parameters which affects the accuracy and outcome of the face mask detection, particularly initial learning rate, batch size, and epoch. Numerous experiments were done in order to tune these 3 parameters so that the outcome of the face mask algorithm will have less error.

If there are applicable information published online, it will be added into the literature review section. For example, during this semester, I have added a new literature review which is about the different types of vision systems that can be implemented. If that particular information affects the methodology section, the methods such as block diagram and flowcharts are updated as well. By continuous learning, the solution proposed is up-to-date, and in line with the latest trends. Between FYRP1 and FYRP2, several adjustments were made to the methodology section, including adding of new features to the project.

A6 Management of Self: Demonstrates self-management processes.

The research project is an individual task, in which I have to complete all the required tasks by my own, with only being guided by my supervisor. As we know that final year research project is an important unit as it provides an opportunity for us to apply what we have learnt in the previous studies to solve real-life engineering problems. For FYRP2, it is mainly about hands on task, such as building of the mechanical prototype using tools and soldering and wiring of circuit boards. These tasks require sufficient planning in order to prevent the prototype from assembled incorrectly. Therefore, before building and assembling the prototype, material sourcing is needed as it details out the types of mechanical components required to build the robot chassis, as well as the fasteners used to secure the connection between the mechanical parts.

A research project requires a strong commitment in carrying out the required tasks, thus self-discipline is very crucial in the project development process. For a steady and on-track progress, proper time management and determination are required.

To keep the project tasks on track, Gantt Chart is always referred. Every time when I noticed that the next task is going to start in a few days, I will always look briefly through about the description of tasks. By doing so, the task can be carried out more easily when it has started.

Logbook

Logbook (Phase 1 – Semester Break)

Familiarisation of the Usage and Configuration of Raspberry Pi Model 4B

During the 1st week of my semester break, I will spend all the time familiarising myself with Raspberry Pi Model 4B hardware. Some of the most important tasks include installing the OS and configuration of Raspberry Pi.

Installation of OS
Recently I have found a website which explains the steps for Python programming using the Raspberry Pi in detail. The website is https://learn.sparkfun.com/tutorials/python-programming-tutorial-getting-started-with-the-raspberry-pi/all#install-the-os. According to this website, there are 2 options which I can interact with the Raspberry Pi.

<u>Option #1: Setup in Full Desktop</u>
In this setup, it includes keyboard, mouse and monitor.

<u>Option #2: Headless Pi (chosen)</u>
From this option, Raspbian Lite can be installed, and it will allow user to get a terminal into the Pi using SSH or Serial on another computer. It also allows user to set tup their Raspberry Pi without a graphical interface.

For the Headless Pi setup, the Raspbian Lite is to be downloaded first before configuring the Raspberry Pi, then the file is unzipped and the image "*2018-03-13-raspbian-stretch-lite.img*" is to be flashed to the SD Card. The program that does this task is called Etcher. The SD card is plugged and the program is run. Figures 22 and 23 show how the NOOBS software is being flashed into the SD card:

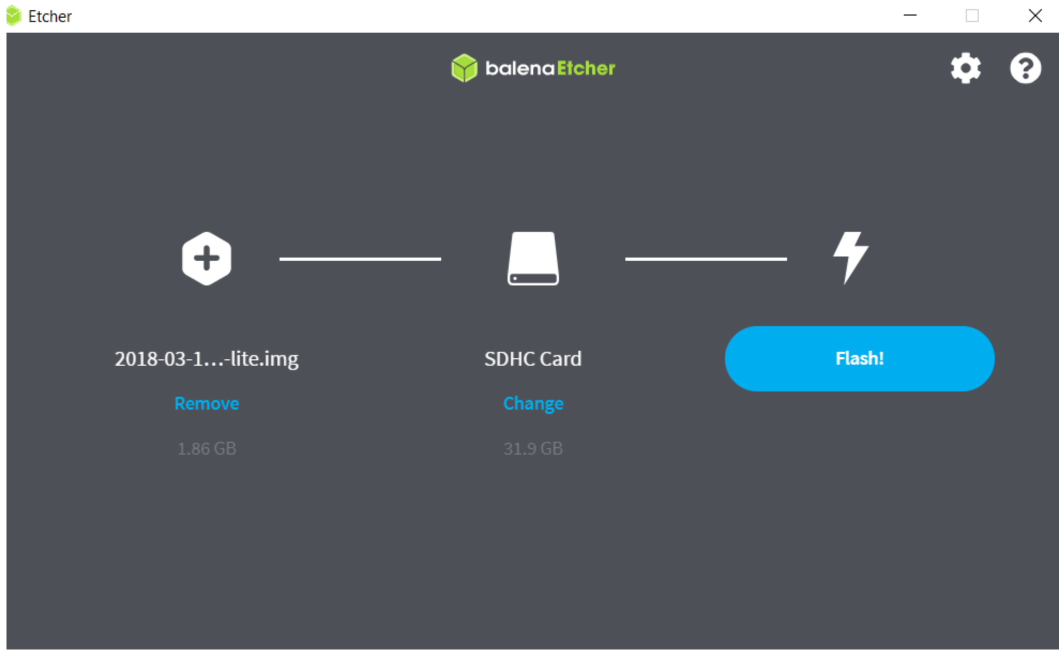


Figure 22: Flashing of the image file downloaded from the website

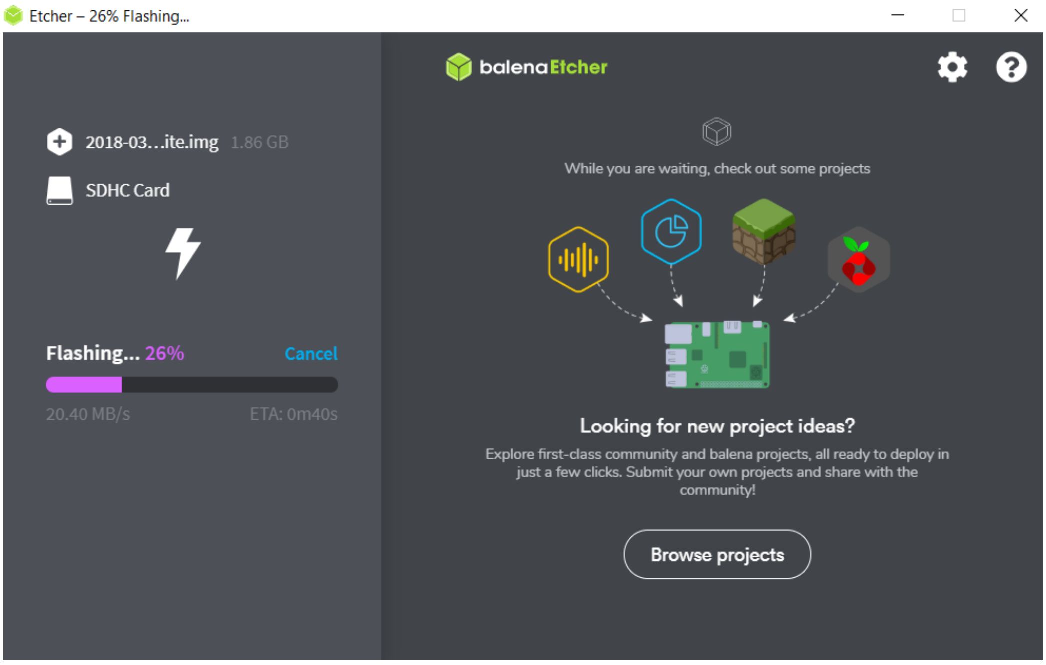


Figure 23: Flashing of the image file into the SDHC card

Serial Terminal

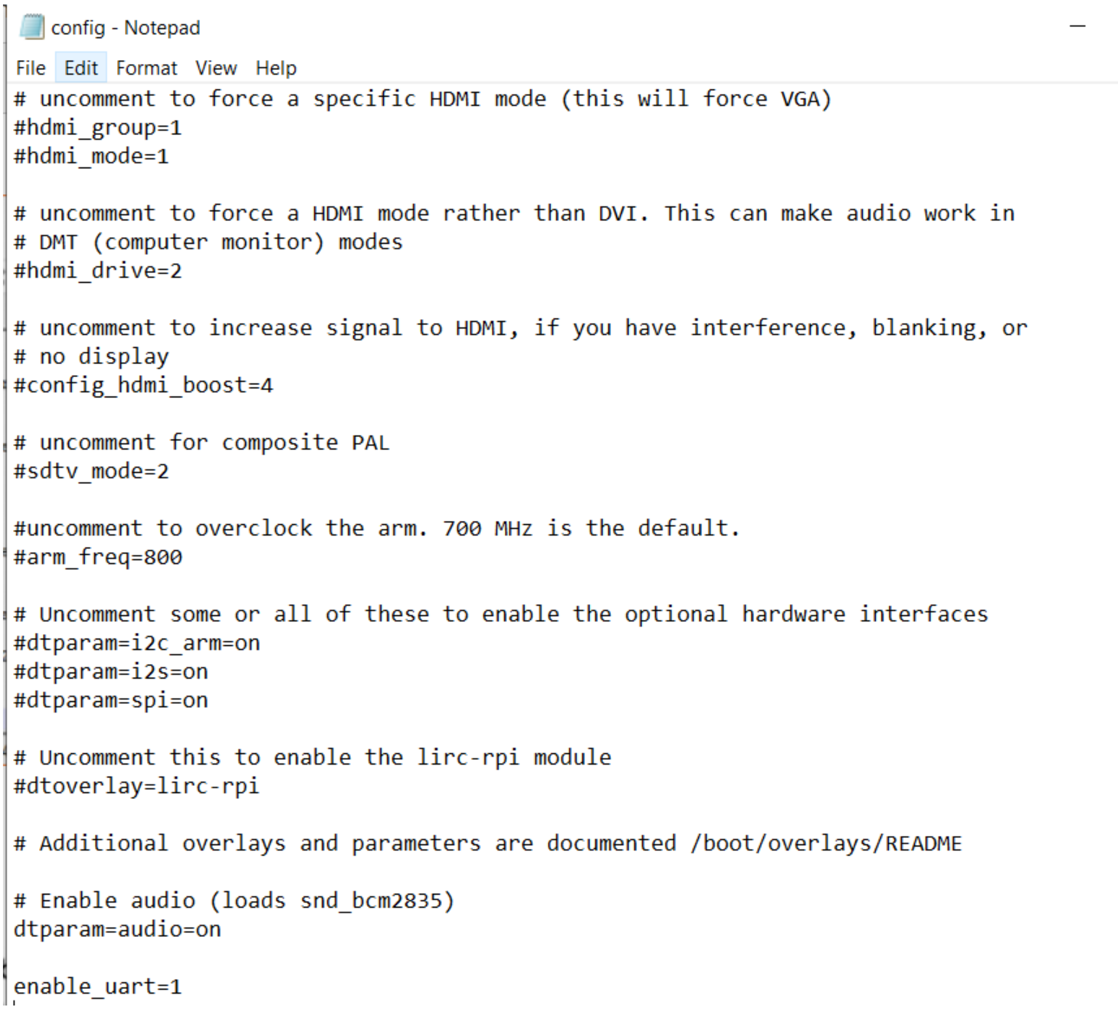
After the OS has been flashed into the SD card, the next thing to carry out is to do Serial Terminal to the Raspberry Pi. It consists of another 3 further ways to configure the Raspberry Pi:

- Serial Terminal (chosen due to its robustness)
- Ethernet with Static IP Address
- Wi-Fi with DHCP

Initially, the Serial Terminal setup is as shown in Figure 24 below:

Figure 24: Initial Setup for Serial Terminal method

The 40-pin GPIO port is connected to the T-Cobbler using the Rainbow Wedge cable as shown in Figure 1 above. With the SD card still plugged in into the laptop, the config.txt file is opened and a line of command is added into the last line of the text file, which is shown in Figure 25 on the next page.



config - Notepad

File Edit Format View Help

```
# uncomment to force a specific HDMI mode (this will force VGA)
#hdmi_group=1
#hdmi_mode=1

# uncomment to force a HDMI mode rather than DVI. This can make audio work in
# DMT (computer monitor) modes
#hdmi_drive=2

# uncomment to increase signal to HDMI, if you have interference, blanking, or
# no display
#config_hdmi_boost=4

# uncomment for composite PAL
#sdtv_mode=2

#uncomment to overclock the arm. 700 MHz is the default.
#arm_freq=800

# Uncomment some or all of these to enable the optional hardware interfaces
#dtparam=i2c_arm=on
#dtparam=i2s=on
#dtparam=spi=on

# Uncomment this to enable the lirc-rpi module
#dtoverlay=lirc-rpi

# Additional overlays and parameters are documented /boot/overlays/README

# Enable audio (loads snd_bcm2835)
dtparam=audio=on

enable_uart=1
```

Figure 25: Adding of new line to enable UART at the config.txt

Study of the Pinout Diagram and the Serial Adapter Function and Connection

As of week 2 of the summer term break, the tasks have been delayed for a few days due to the purchasing of new component which took a few days to receive. The next step is to connect a FTD1232 Serial from PC to the Raspberry Pi Model 4B pins. Figure 26 shows the pinout diagram for Raspberry Pi Model 4B.

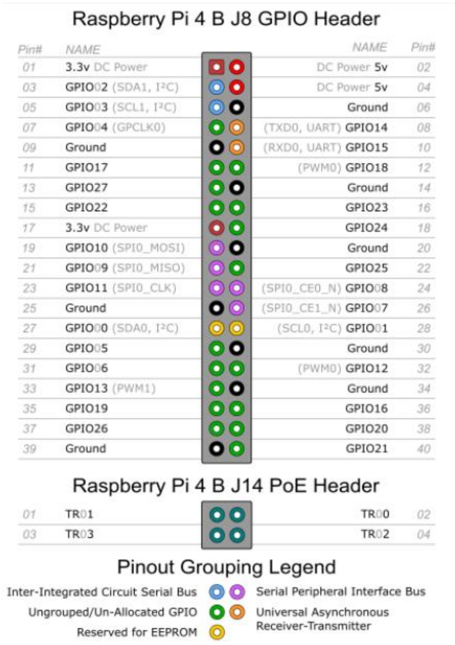


Figure 26: Raspberry Pi Model 4B Pinout Diagram

Figure 27 shows the connection of FTD1232, in which four female-header jumper wires are connected to the output, and the input is connected with a micro-USB cable to USB cable.

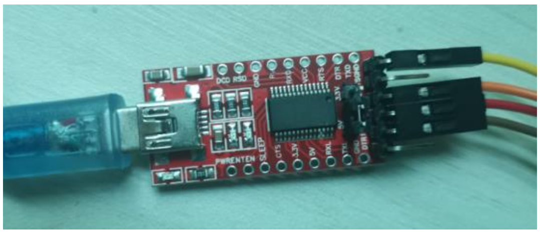


Figure 27: Hardware Connection of FTD1232

Figure 28 shows the final connection after adding the Raspberry Pi wedge connector. (GPIO extension board)

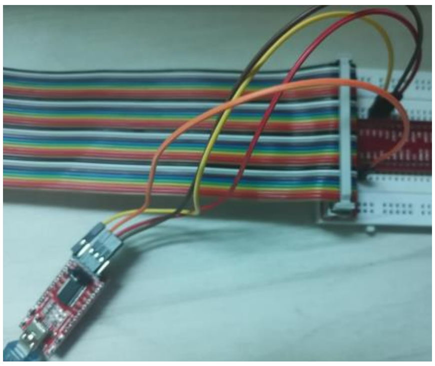


Figure 28: Connection from FTD 1232 to Raspberry Pi Wedge Connector

From the pinout connection, pins 8 and 10 are connected to the UART TXD and RXD pin of the Raspberry Pi respectively. After all the necessary connections have been made, Device Manager is opened in order to know the COM Port Number connected to the USD to serial adapter.

Outcome of using Serial Method: Fail due to some difficulties in reading the USB port number which is responsible for connecting the laptop to the serial adapter. (Shown in Figure 29)

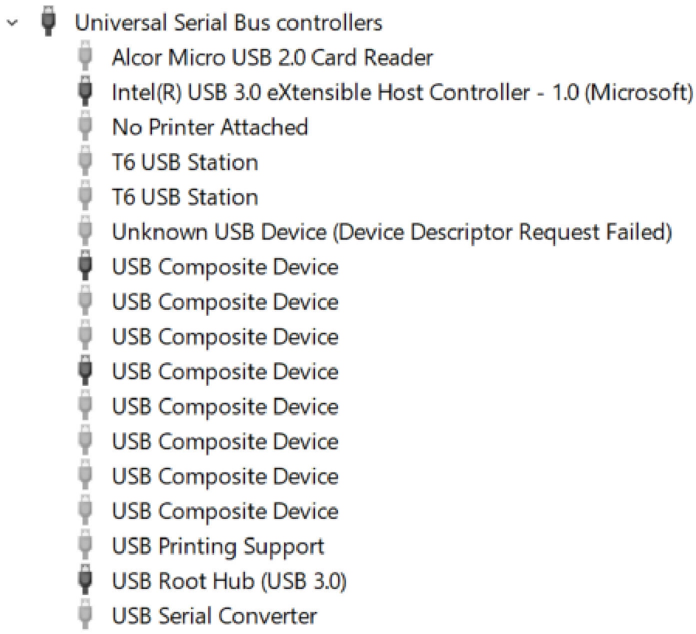


Figure 29: USBs connection status in Device Manager

From Figure 29, the USB Serial Converter is not lighting up even if the serial adapter has been connected from laptop to the TX0 and RX0 of the Raspberry Pi 4B. As a result, the ports indication is not working as expected, which can be shown in Figure 9 below. This situation seems more obvious when the LED on the Serial Adapter is not lighting up despite the connection between laptop and Raspberry Pi 4B has been connected physically. Thus, the serial terminal connection is not working properly. Figure 30 below shows the Ports connection status, which is not detected at all due to the light grey shade on the icons.

Figure 30: Ports Connection in Device Manager

Plan B: Flashing NOOBS software into the SD card which will be mounted into the bottom slot of the Raspberry Pi 4B.

Another method of configuring Raspberry Pi 4B is using desktop setup instead of using Headless setup. This involves external keyboard and mouse device which are connected to the USB port of the Raspberry Pi 4B. First, a 32GB capacity SD card is used for the data transfer during the configuration. However, the SD card needs to be formatted using a software called SD Card Formatter, as shown in Figure 31 below:

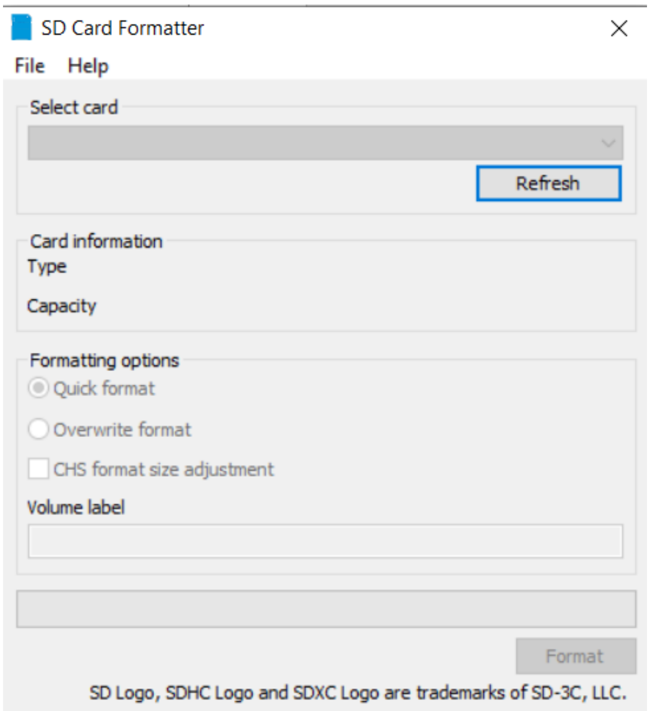


Figure 31: SD Card Formatter interface

After formatting the SD card properly, the NOOBS software is downloaded from website called https://www.raspberrypi.org/downloads/noobs/. From the website, NOOBS in the form of zip file is downloaded, not the NOOBS Lite as NOOBS Lite does not contain the Raspberry Pi OS pre-installed. Figure 32 shows the choosing of file required to download NOOBS from the website mentioned above:

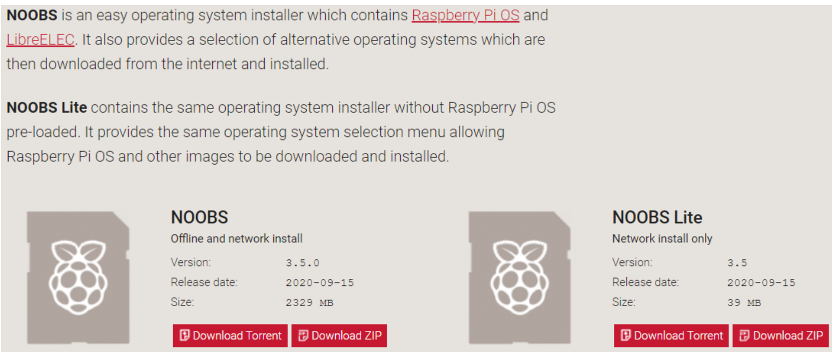


Figure 32: Downloading of NOOBS software from the website (choose the zip file on the left)

After downloading the NOOBS software, the zipped folder is extracted into one of the folders in the laptop. All the documents inside that extracted file are copied and pasted into the SD card, as shown as Figure 33 below:

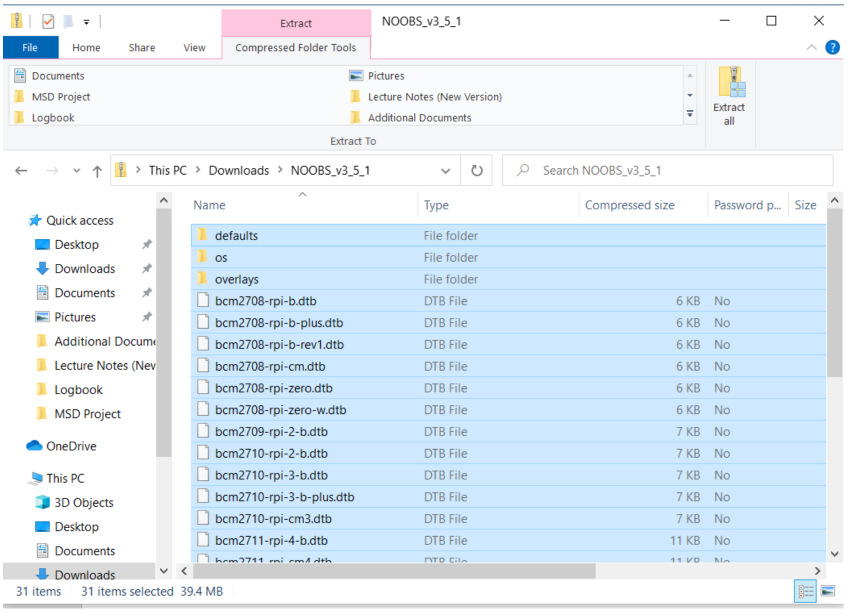


Figure 33: Data Copying from zipped file into SD Card

SD Card Inserting and Hardware Connections to Raspberry Pi 4B

Upon completion of the data transferring process, the card is ejected from the laptop and is inserted into the SD card slot underneath the Raspberry Pi 4B, as shown as in Figure 34 below:

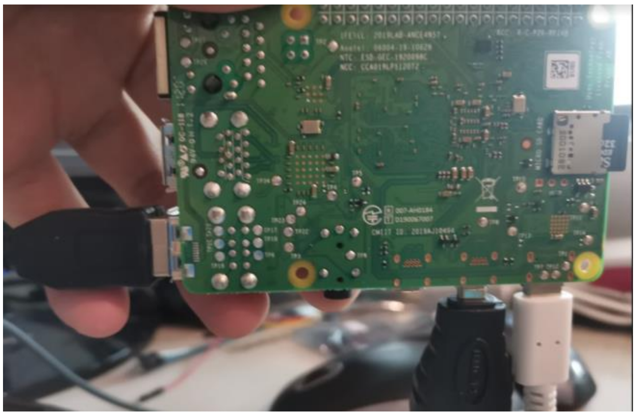


Figure 34: Illustration of where the SD card should be inserted into the slot

The following hardware are required to be plugged into the different ports of Raspberry Pi 4B:

- ✓ Wired Keyboard (to USB 2.0 port)
- ✓ Wired Mouse (to USB 2.0 port)
- ✓ Wall Adapter for the power source (to USB type C port)
- ✓ Monitor (to mini HDMI0 port)

Figure 35: Illustration of all the Hardware Connections to the Raspberry Pi 4B

In Figure 35 above, it can be seen that multiple adapters (one for VGA-HDMI adapter and another one for HDMI to mini-HDMI adapter are used in connecting the monitor to the Raspberry Pi 4B). This is because the first adapter is for connection between the laptop and the monitor whenever necessary, the second adapter is used only if connection to the Raspberry Pi 4B is needed.

Powering on the Raspberry Pi 4B

After all the hardware connections has been done, it is the time to power up the mini computer. Upon powering up the Raspberry Pi 4B, a rainbow figure is displayed on the monitor screen for a few seconds, which can be seen clearly in Figure 36 below:

Figure 36: Display of Rainbow screen upon the booting process

After a few seconds, a window popped out on the screen, the Raspberry Pi OS Full (32-bit) is installed by ticking the selection box and the Install button is clicked, thus starting the installation of OS system, as shown in Figure 37 below:

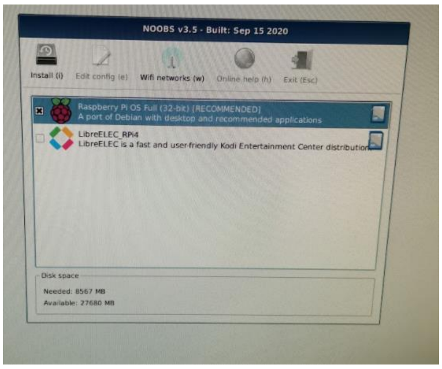


Figure 37: Pop up Window for the OS Installation.

The installation took around less than 20 minutes, then another window popped out, which indicates that the OS has been installed successfully. The button “Next” is clicked to proceed, while at the same time the IP address for this Raspberry Pi 4B is displayed at the bottom right corner of the window. For the device, the IP address is 192.168.0.4. This IP address will later be used for SSH connection at the laptop other than on the monitor connected to the Raspberry Pi 4B, shown in Figure 38 below:

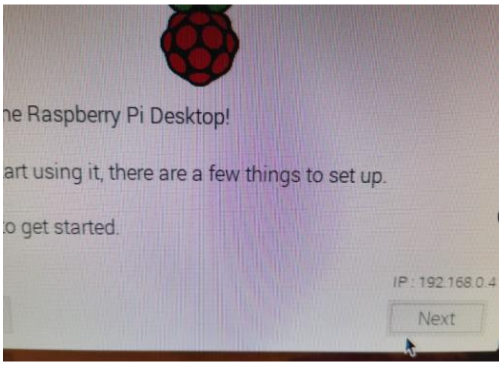


Figure 38: Window showing the IP address of the Raspberry Pi 4B

The 2nd window asks for the Region Setting. In this case, the country selected is Malaysia, with English language being used, together with US Keyboard shown in Figure 39 below:

Figure 39: Region and Language Setting

After clicking ‘Next’ button, the 3rd window appears, this time asking for password change. By default, ‘pi’ will be the username when using Raspberry Pi 4B on desktop. And ‘raspberry’ is the default password for logging in. However due to the security factor, it is recommended that the password is changed. It can be changed later after logging in, shown in Figure 40 below:

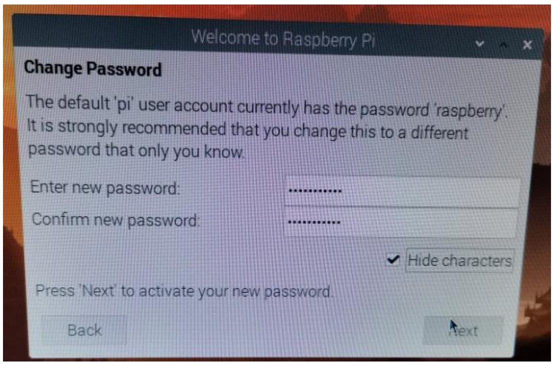


Figure 40: Changing of Password

The final window that appeared is the Software Update window. For this case, the update list is checked in order to see whether there is an update available. (shown in Figure 41 on the next page)

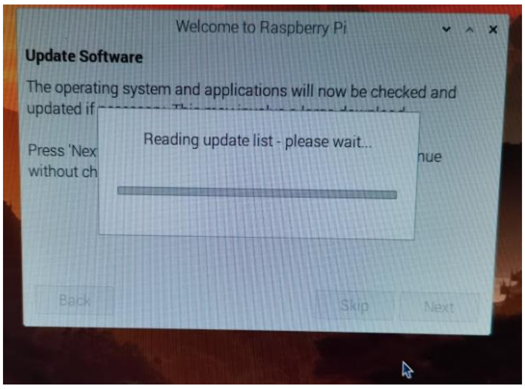


Figure 41: Software Update Checking

After a few moments, the initial setup has been done, which directed me to the Desktop Interface, as shown in Figure 42 below:

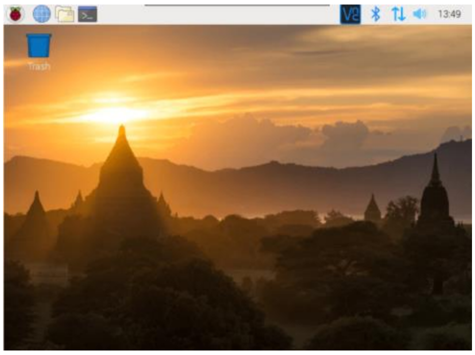


Figure 42: Initial Desktop Background Interface

Until this stage, it can be said that the initial setup has been done completely.

Additional Raspberry Pi 4B Configuration

After successfully setting up the OS system, one of the thing that has been done is carrying out additional configurations on the Raspberry Pi 4B, this can be done by selecting the Raspberry Pi icon on the top left corner, then choose Preferences > Raspberry Pi Configuration.

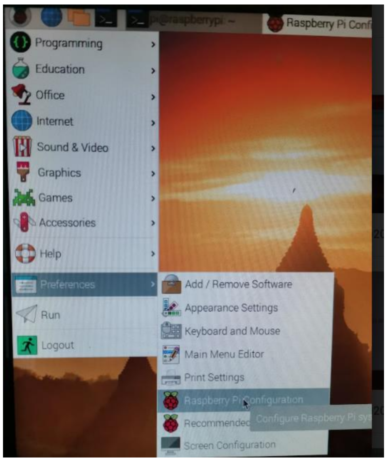


Figure 43: Location of where to find the Raspberry Pi Configuration

In Figure 43, after clicking the selection, Interfaces section is selected in order to enable which interfaces to be used in this project, which is seen at Figure 44 on the next page.

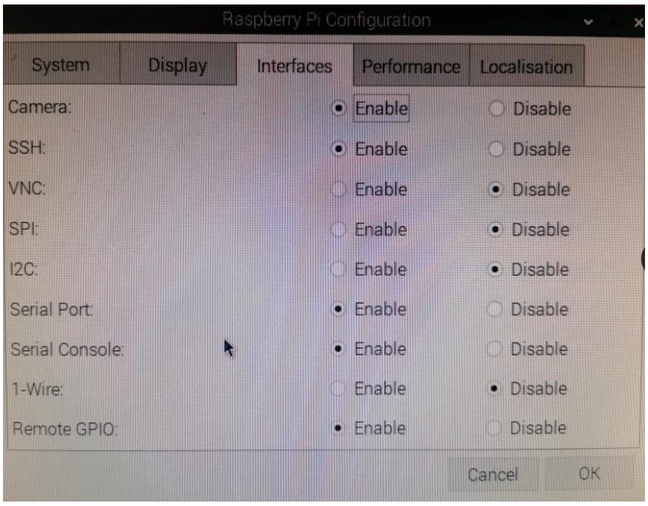


Figure 44: Enabling of some Interfaces which will be used later

Logging in and Carrying out Further Configuration using the Terminal Icon

The terminal is located 3 icons to the right of the Raspberry Pi icon. After clicking the icon, a command prompt-like window popped out and the command is typed in. Initially, the log in using SSH, the command ssh pi@[IP Address of the Raspberry Pi 4B] is typed in, as shown in Figure 45 below:

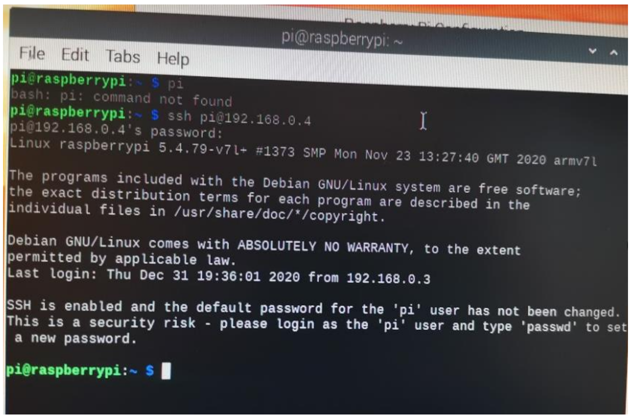


Figure 45: Terminal showing the enabling of SSH connection for Raspberry Pi 4B

From the Terminal window, it can be seen that the command ‘passwd’ can be used for changing of password when in SSH connection, which can be seen in Figure 46

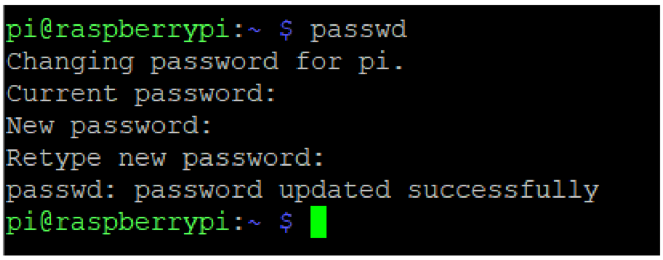


Figure 46: Changing of Password using the command password

Testing of Program using Built-In Software in Raspberry Pi 4B (Part 1)

Since I'm only exposed to Raspberry Pi 4B 2 weeks ago, therefore I will try to use the built-in software inside Raspberry Pi 4B, which is called Mu 1.0.2. The first program that is tested is blinking an LED for a certain duty cycle. Figure 47 below shows how the blinking circuit is being setup.

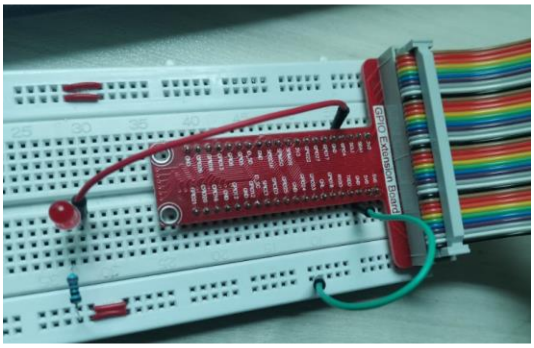


Figure 47: Setup of the LED blinking circuit

From the circuit setup, GPIO4 is used for the output pin to control the LED blinking. A 220 Ω resistor is used to connect the LED to the ground. Based on the code snippet below, a simple loop function is written to continuously blink the LED with on and off time of 0.5 second.

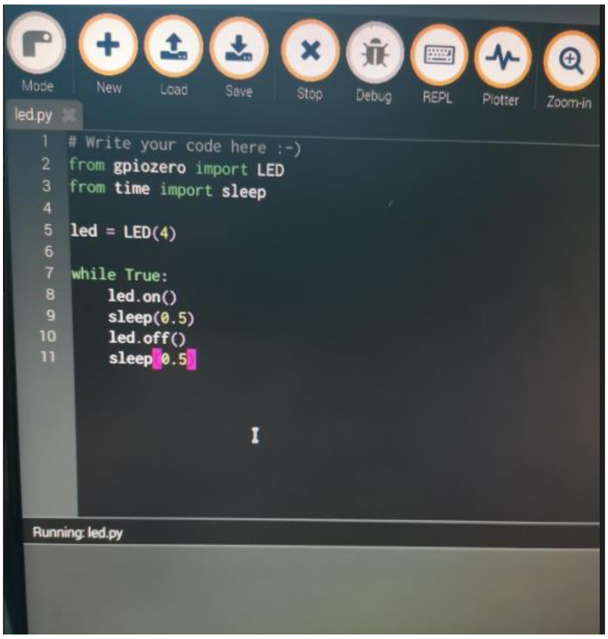


Figure 48: Code Snippet for LED blinking test

From the source code in Figure 48 above, there are 2 libraries which are imported. The *gpiozero* indicates the use of GPIO pins, whereas the *sleep* function indicates the time period for that line of command.

During the 2nd week of Summer Break, I have managed to configure Raspberry Pi 4B using the desktop method by transferring data from the NOOBS folder into the SD card, and I have also managed to configure the mini computer on the desktop by carrying out necessary testing on the built-in software. For the next 1-2 weeks, I will learn how to transfer coding from external software (Spyder) in my laptop to Raspberry Pi 4B, which can be done using USB flash drive. During the next few weeks, more testing will be done to various circuit components such as buzzer, button switches, 4x3 keypad, and finally the Raspberry Pi Camera. Besides, I will try to learn programming for web and app development as the project scope involves Wi-Fi implementation.

Useful Software Links (Summer Break Week 2)

https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html

https://www.raspberrypi.org/documentation/remote-access/ip-address.md

https://realpython.com/python-raspberry-pi/#setting-up-the-raspberry-pi

https://www.pishop.us/first-look-at-raspberry-pi-4/

https://magpi.raspberrypi.org/articles/set-up-raspberry-pi-4

https://thepi.io/how-to-install-noobs-on-the-raspberry-pi/

https://www.raspberrypi.org/downloads/noobs/

https://www.sdcard.org/downloads/formatter/eula_windows/index.html

https://www.quora.com/What-is-the-way-to-install-PyCharm-Professional-for-free

https://www.raspberrypi.org/documentation/usage/gpio/python/README.md

https://www.elithecomputerguy.com/2020/06/raspberry-pi-how-to-begin-coding-python-on-raspberry-pi/

https://www.youtube.com/watch?v=oikrc1lEMXg

https://www.raspberrypi.org/documentation/remote-access/vnc/

Connecting to Raspberry Pi 4B using VNC Viewer

Apart from using SSH to control Raspberry Pi 4B from my laptop, I have discovered another simple yet more convenient way to remotely control my Raspberry Pi 4B from another place, provided that the IP address of the Raspberry Pi 4B device is known (which is a YES in this case).

To do so, first the VNC Viewer needs to be downloaded from my laptop (Install for Windows) and then installed it. On the other side, the VNC Viewer can be installed from the Raspberry Pi 4B using the Terminal. After logging in using the username and password, the command *sudo apt-get update* and another command *sudo apt-get upgrade* are typed in to check whether any updates are available. Figure 49 below shows the Checking Updates status before installing VNC Viewer on Raspberry Pi 4B.

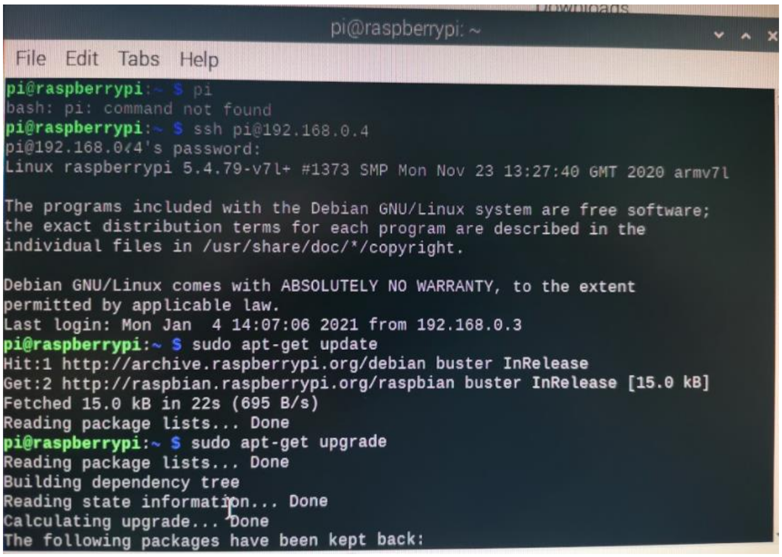


Figure 49: Checking Updates Before Installing VNC Viewer on Raspberry Pi 4B

After checking the updates, the next thing to be carried out is typing in the command *sudo apt-get install realvnc-vnc-viewer*, which is shown in Figure 50 below:

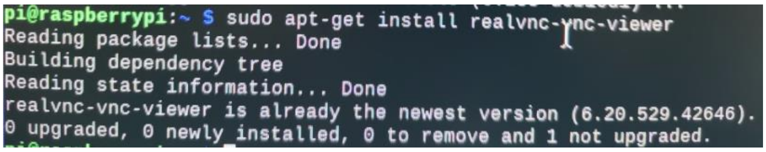


Figure 50: Installing VNC Viewer using the command

After the installation has been completed, the command sudo raspi-config is typed, this is for configuration of VNC enabling, as shown in Figure 51 below:

Figure 51: Configuration for Enabling VNC

Upon entering the command, a new interface window ap pears as shown in Figure 52 below, and Interface Option is chosen:

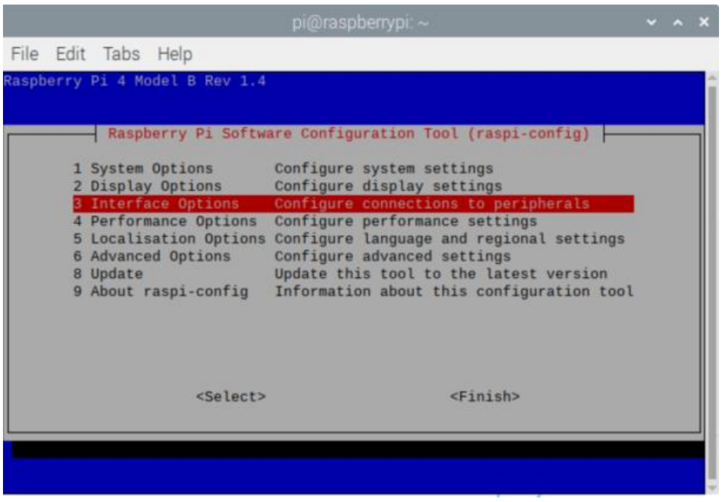


Figure 52: Interface Options

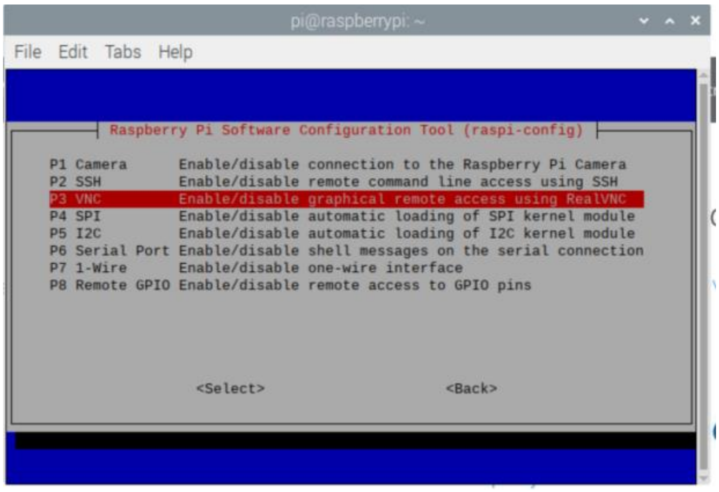


Figure 53: Enabling of VNC in Raspberry Pi Software Configuration

In Figure 53 above, the 3rd option is chosen to enable the VNC in Raspberry Pi. Upon enabling marks the end of the installation of VNC Viewer in both devices (laptop and Raspberry Pi 4B). The next thing which is done is activate the VNC Viewer connection between 2 devices. From the laptop, the IP address pf the Raspberry Pi 4B is typed into the Search box, as shown in Figure 54 below:

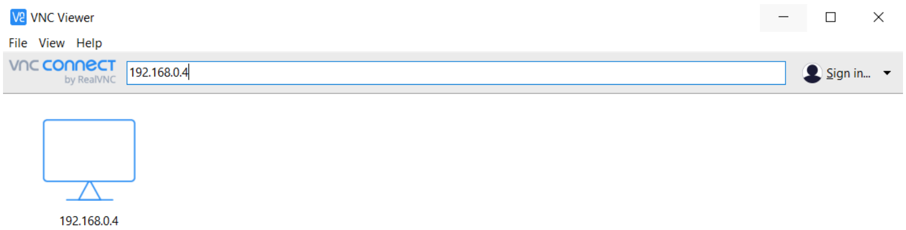


Figure 54: Connecting to Raspberry Pi 4B from laptop's view

Upon the successful connection, the Raspberry Pi can be fully controlled by the laptop's command, as shown in Figure 55 below:

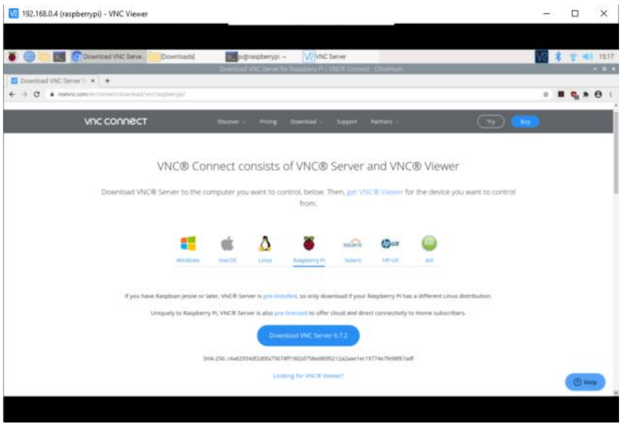
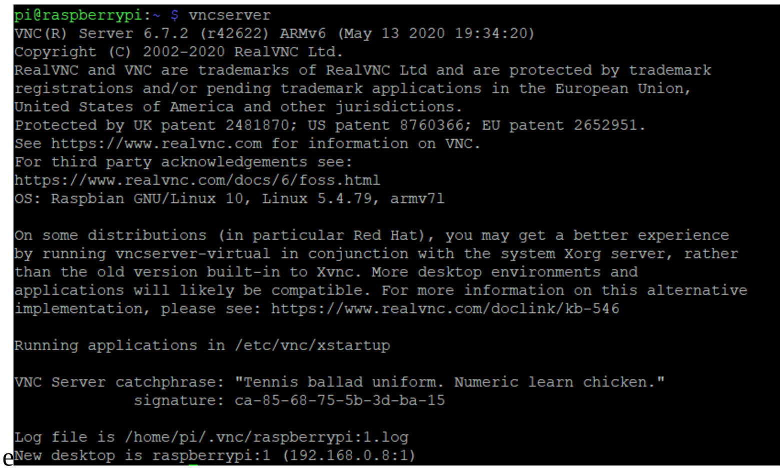


Figure 55: Raspberry Pi Interface from Laptop's View

Create a Virtual Desktop from Laptop without connecting to the Monitor

In the previous activity being carried out, a HDMI cable and adapter are used to connect the Raspberry Pi 4B to the monitor, so that the interface can be seen from the monitor. For this task, a virtual desktop will be implemented such that the Raspberry Pi can be controlled further away from laptop without being connected to the monitor. To do so, the IP address of the Raspberry Pi 4B is determined and is used to configure the PuTTY Configuration software. Upon logging in with the required username and password, the command *vncserver* is typed inside the PuTTY Configuration. Upon doing so, the new IP address is shown in Figure 56 below. Using the updated IP address, it is used to activate the VNC Viewer from the laptop.



```
pi@raspberrypi:~ $ vncserver
VNC(R) Server 6.7.2 (r42622) ARMv6 (May 13 2020 19:34:20)
Copyright (C) 2002-2020 RealVNC Ltd.
RealVNC and VNC are trademarks of RealVNC Ltd and are protected by trademark
registrations and/or pending trademark applications in the European Union,
United States of America and other jurisdictions.
Protected by UK patent 2481870; US patent 8760366; EU patent 2652951.
See https://www.realvnc.com for information on VNC.
For third party acknowledgements see:
https://www.realvnc.com/docs/6/foss.html
OS: Raspbian GNU/Linux 10, Linux 5.4.79, armv7l

On some distributions (in particular Red Hat), you may get a better experience
by running vncserver-virtual in conjunction with the system Xorg server, rather
than the old version built-in to Xvnc. More desktop environments and
applications will likely be compatible. For more information on this alternative
implementation, please see: https://www.realvnc.com/doclink/kb-546

Running applications in /etc/vnc/xstartup

VNC Server catchphrase: "Tennis ballad uniform. Numeric learn chicken."
             signature: ca-85-68-75-5b-3d-ba-15

Log file is /home/pi/.vnc/raspberrypi:1.log
New desktop is raspberrypi:1 (192.168.0.8:1)
```

Figure 56: Updated IP address shown in the bottom of the PuTTY Configuration window

From the window, the updated IP address is 192.168.0.8:1 (additional :1 at the back), shown in Figure 57 below:

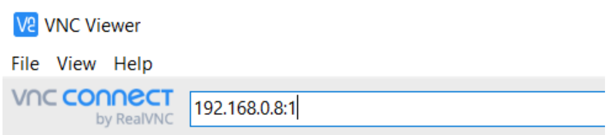


Figure 57: Entering new IP address into the VNC Server

Upon finishing entering the IP address, the virtual desktop has been created without the setup of a desktop monitor.

Transfer of Python Files from Laptop to Raspberry Pi using SSH

After various method of transferring the program from the laptop to Raspberry Pi 4B, I have come out another better method of doing so rather than using VNC Viewer, which is using SSH. For SSH method, the software that I used to write the program is called JetBrains PyCharm Professional. Usually, PyCharm Community is a free software which is for basic operation. However, I have found a student version for PyCharm Professional which has further features such as SSH Interpreter which is essential for remote accessing without using external software such as PuTTY and VNC Viewer. The website for downloading the student version is
https://www.jetbrains.com/community/education/#students

After successfully installing the student version for the software, a new project has been created. To configure the SSH remote accessing, click File > Settings, and then the 'Add Interpreter' is chosen, followed by SSH Interpreter, as shown in Figure 58 below:

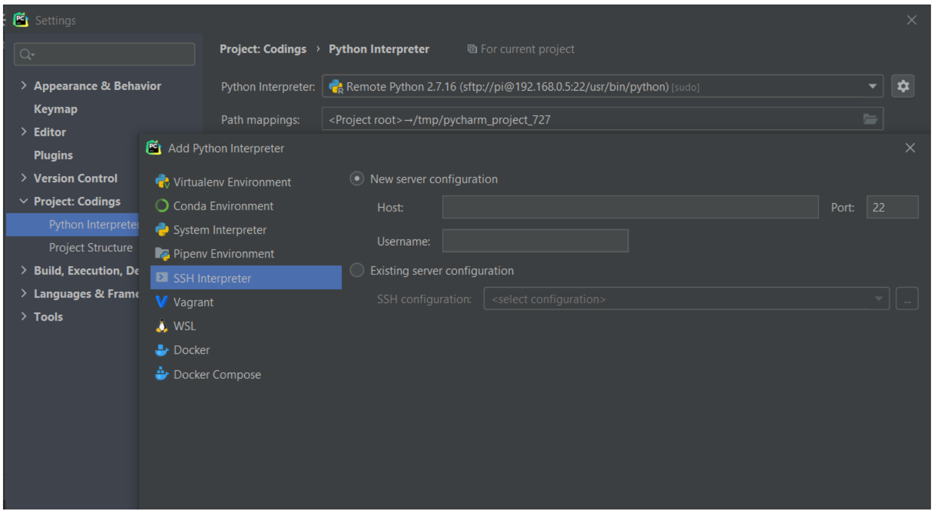


Figure 58: Configuration of SSH Interpreter in PyCharm Professional

From the SSH Interpreter, the host name is the IP address of the Raspberry Pi 4B being used, and the username is the default (pi). After various clicking of the 'Next' button during the configuration phase, the software is able to connect to the Raspberry Pi 4B using the IP address.

Based on the software, the main advantages of using it is that it has built-in SSH configuration which is suitable for remote access. However, one of the drawback is that every time a new project is created, all the required libraries are to be downloaded in the software.

Steps to Configure SSH Interpreter every time Raspberry Pi is being restarted:

Step 1: Restart PyCharm

Step 2: Log in SSH in PuTTY Configuration.

Step 3: Delete the previous SSH Interpreter and Connection (Found in Settings > Deployment)

Step 4: Re-add a SSH Interpreter using the IP address

Step 5: Wait until the file has been transferred successfully (Do not straight change the setting from Default Configuration to SSH)

Step 6: Re-enter Settings and Edit the SSH (Change Default Configuration to SSH), then RUN!

Testing of Ultrasonic Sensor (Sensor Testing #1)

In this testing, the program is written to enable the ultrasonic sensor to carry out the task of measuring distance. Unlike other distance measuring sensors, ultrasonic sensor consists of 2 pins which are responsible for the distance measuring. Figure 59 shows the connection of ultrasonic sensor using jumper wire connection:

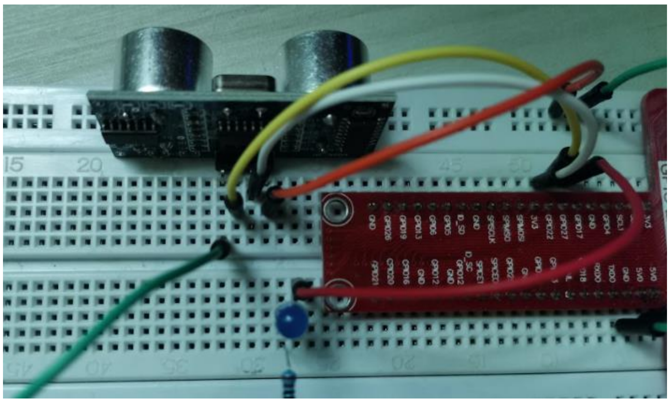


Figure 59: Jumper Wiring Connection of the Ultrasonic Sensor

To configure the ultrasonic sensor, first the pin number are declared, as well as the type of pin. In this case, GPIO22 is connected as output to the trigger pin of the sensor, as the trigger pin sends out the pulse, while the echo pin which is connected to GPIO27 receives the reflected pulse from the detected object, thus the echo pin is of input type. Figure 60 below shows the code written for setting up the GPIO.

```python
import RPi.GPIO as GPIO
import time

GPIO.setmode(GPIO.BCM)

# Define the pins for the Ultrasonic Sensor
TRIGGER = 22
ECHO = 27

# Setup GPIO Direction and Default Value
GPIO.setup(TRIGGER, GPIO.OUT)
GPIO.setup(ECHO, GPIO.IN)
```

Figure 60: Code Snippet for the GPIO setup (Sensor Testing #1)

Initially, the trigger pin sends out a rising-edge pulse with very short duration of 0.1 ms, until the command `GPIO.output(TRIGGER, False)` stops sending the pulse by inducing a falling edge to it. At the instant when the edge pin sends out the rising-edge signal, the echo pin does not receive the signal from the echo pin yet, hence the time when the initial time is recorded using the command `start = time.time()`. After the reflected pulse is sent back from the detected object, the echo pin will indicate that it has received the signal, thus the final time is recorded again using the code `final = time.time()`. The difference between these 2 periods of time is calculated, indicating the time taken for the signal to send out by the trigger pin and to be received from the echo pin. Figure 61 on the next page shows how the Trigger and Echo pins are being configured.

```python
30 while True:
31     #Trigger pin sends a pulse with very short duration
32     GPIO.output(TRIGGER, True)
33     time.sleep(0.0001)
34     GPIO.output(TRIGGER, False)
35 
36     # Wait until the echo pin receives the reflected signal pulse
37     while (GPIO.input(ECHO) == False):
38         start = time.time()
39     while (GPIO.input(ECHO) == True):
40         end = time.time()
41 
42     #Time difference between the period when the signal is sent out and is received
43     sig_time = end - start
44 
45     #Display the distance in cm.
46     distance = sig_time/0.000058
47     print(format(distance, ".2f"))
48 
49     time.sleep(0.5)
```

Figure 61: Code Snippet for Configuring the Trigger and Echo pins

From the code snipper in Figure 61, the configuration of the trigger and echo pins is from line 31 to line 43. To calculate the distance between the sensor and the object, the difference between the two periods of time is divided by 0.000058, thus calculating the final result in cm. Additionally, a 0.5s delay is implemented so that the distance measurement can be updated at a faster rate.

Testing of IR sensors from different height

IR sensor testing is required such that the voltage read from the sensor in different coloured surface detected needs to be obtained. Additionally, different values of the distance between the sensor and the ground are used, ranging from 2 cm to 5 cm with 1 cm increment. Figure 62 below shows the vertical setup of the IR sensor on breadboard:

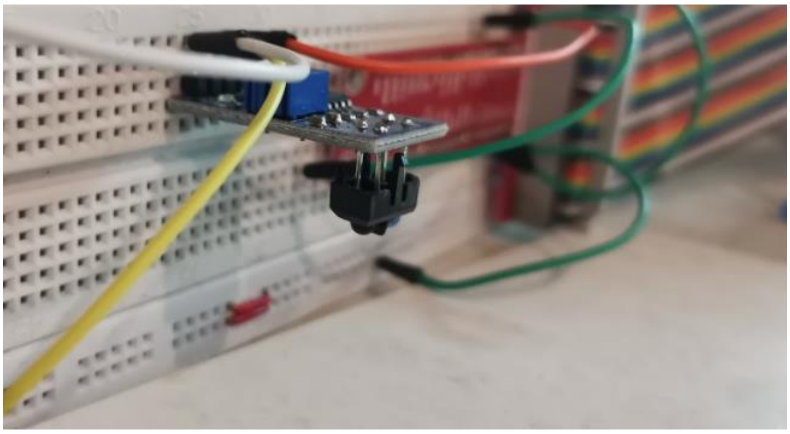


Figure 62: Setup of the IR Sensor testing

From the setup of the circuit in Figure 62, the IR sensor is connected to the breadboard which is held vertically in order for the IR sensor to detect the ground surface. Each time when the IR sensor detects the surface at different height, the voltage reading will be observed and recorded in the tabulation of data. Table 2 below shows the data collected for the IR sensor input voltage obtained vs the height.

Table 2: Tabulation of Different Height and Colour of surface on the Sensor Voltage

	Input IR Sensor Voltage (V)		
	Black/Dark Grey surface	**White surface**	**Yellowish surface**
Height, h (cm)			
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

Logbook – Phase 2 (Last week of Semester Break – Week 3)

Material Sourcing (Last week of Semester Break)

Before purchasing all the components, they are required to be sourced by considering the dimension of the robot base which is 30 cm x 30 cm x 50 cm. For the robot base, MDF board of 30cm by 30cm will be used, as well as the base for the 2nd compartment level. The 1st and 2nd compartment level needs to be supported by pillars made from aluminium square hollow bar. For the robot base frame, 4 L-shaped bracket tube connectors are needed, and 8 rivets of diameter 3.2 mm are required to connect the aluminium square hollow tube so that it forms a frame. The list of bars and their length are shown in Table 3 below:

Table 3: List of the Aluminium Square Hollow Bar required for each place

Placement of the Aluminium Square Hollow Bar	
Frame for the Robot Base	25 cm (4 pieces)
Support Pillar for 1st compartment	14 cm (4 pieces)
Support Pillar for 2nd compartment	19 cm (4 pieces)

Based on Table, the total length of the aluminium square bar required is:

$$Total\ Length = 4(25) + 4(14) + 4(19) = 232\ cm \approx 8\ feet$$

For the connection of the pillars to the robot, L-shaped is used to connect the pillars to the robot, and each pillars require 2 L-shaped bracket for upper and lower side. Therefore, 8 pillars require 16 L-shaped bracket of dimension 40 mm x 40 mm. Table 4 lists the screws used for securing each part of the L-shaped bracket to the robot.

Table 4: List of the Screws Required for Connecting the L-shaped bracket and the pillars and base/top cover

Components	**Quantity**	**Uses**
M4*40 machined screw (stainless steel, flathead screw)	16	Secure the L-shaped bracket and the pillars for 1st and 2nd compartment
M4*20 machined screw (stainless steel, flathead screw)	16	Secure the L-shaped bracket and the 2nd level wooden base and the top cover
Wood Screw (M4*10)	8	Secure the L-shape bracket to the robot base.

For the wheel and shaft, Table 5 shows the following parts that are required:

Table 5: List and Quantity of the Parts required for the wheel and shaft

Components	**Quantity**	**Uses**
Shaft (10cm – 8mm diameter)	1	Connects DC Motor and 2 front wheels
Shaft (40cm – 8mm diameter)	1	Used for back wheels
Motor Shaft Coupling (6 mm to 8 mm)	2	Connects motor shaft and 8 mm shaft
KFL08 bearing	4	Support the 8 mm shaft that is connected to the wheel
Wheel Hex Coupling	4	Secures the wheel to the 8 mm diameter
Wheel (65mm)	4	For robot motion purpose
M4*50 machined screw (stainless steel, flathead screw)	8	Used to secure the bearings to the robot base.

For the side and top covers of the robot prototype, Table 6 lists the parts and quantity needed:

Table 6: List and Quantity of the Parts required for the prototype covers

Components	Quantity	Uses
Aluminium Composite Panel (30 cm x 30 cm)	1	Top Cover
Aluminium Composite Panel (45 cm x 30 cm)	4	Side Covers

After listing out all the parts required for each section, Table 7 shows the finalised mechanical components required for building up the prototype assembly (without including 3D-printed parts):

Table 7: Finalised Parts Required to build the prototype

Components	Quantity
Aluminium Square Hollow Bar (1 inch by 1 inch)	8 feet
Aluminium Composite Panel (30 cm x 30 cm)	1
Aluminium Composite Panel (45 cm x 30 cm)	4
Shaft (10cm – 8mm diameter)	1
Shaft (40cm – 8mm diameter)	1
Motor Shaft Coupling (6 mm to 8 mm)	2
KFL08 bearing	4
Wheel Hex Coupling	4
Wheel (65mm)	4
M4*50 machined screw (stainless steel, flathead screw)	8
M4*40 machined screw (stainless steel, flathead screw)	16
M4*20 machined screw (stainless steel, flathead screw)	16
Wood Screw (M4*10)	8
L-shaped bracket tube connectors	4
Rivets (3.2 mm)	8
L-shaped Metal Bracket	16

Procedures of Building and Assembling of Prototype (Week 1-3)

Stage 1: Building of Base

At the 1st stage of assembly, the base must be built by connecting the aluminium square hollow tubes with the L-shaped bracket, followed by inserting rivets between the bracket and the aluminium bar to hold on its position, as shown in Figure 63 below:

Figure 63: Connecting Aluminium Square Hollow Bar with backet using rivet

Upon securing the aluminium square frame, the next step that must be done is to drill 8 holes of diameter approximately 4 mm at the 4 sides of the aluminium frame. The purpose of doing so is to connect bearing with the frame using 8 screws (M4*50) and 8 M4 nuts. Figure 64 below shows how the bearing and the frame are secured using screws and nuts.

Figure 64: Securing the bearing and the frame using screws and nuts

The resultant assembly needs to be connected with the wooden board of thickness around 10 mm. Therefore, M4 screws of length 50 mm is sufficient for it to connect through the bearing, frame, and the wooden board with some more length left for nut securing.

Step 2: Building of 1st level with 4 aluminium hollow bars.

After the wooden board is assembled together with the frame, the 4 aluminium bars are cut and are required to be placed on the 4 corners of the board. The aluminium bars are connected with the board using L-shaped bracket of length 50 mm each. 2 holes are drilled on each aluminium bars, so that screws can be fitted through the hollow bars. Before drilling, markings are made so that the L-shaped bracket can be connected properly with the aluminium hollow bar without any misalignment, as shown in Figures 65 and 66 below:

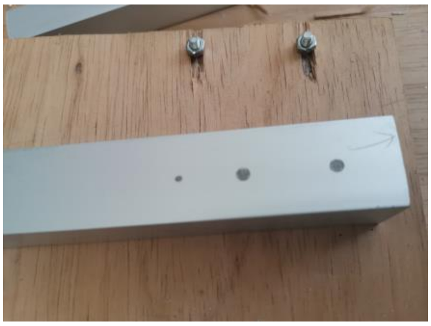


Figure 65: Pencil marks on the bar before drilling.

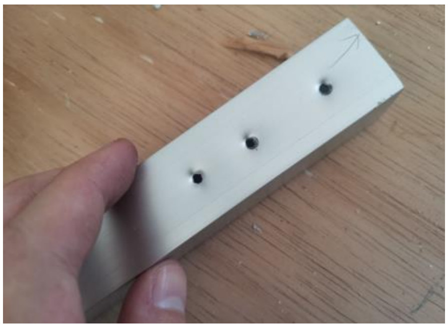


Figure 66: Drilling on the Aluminium Hollow Bar

In Figure above, despite only 2 holes are required for each aluminium hollow bar, the 3rd drilled hole will be used later, which is for securing the outer cover with the aluminium bar using screws. The screws used to connect the aluminium bar and the L-shaped bracket are of dimension M4*35, since the width of the aluminium is about 2.5 cm (or 1 in.).

Figure 67: Connecting L-shaped brackets and aluminium bar

In Figure 67 above, the 4 aluminium bars connected with the brackets will be secured on the wooden board using 8 wooden screws of length 10 mm. These assembly will act as the 4 pillars which connect between the ground level of compartment and the 2nd level of compartment.

After placing the 4 pillars on the 1st level wooden block, a 2nd wooden block is placed on top of the 4 pillars as the 2nd level compartment. Here, 8 screws of dimension M4*25 are used.

After placing the 4 pillars on the 1st level wooden block, a 2nd wooden block is placed on top of the 4 pillars as the 2nd level compartment. Here, 8 screws of dimension M4*25 are used. Figure 68 below shows the securing of L-shaped bracket onto the pillar and base viewed from the bottom

Figure 68: Securing 2nd level wooden block with brackets

For the other 4 pillars, same process will be carried out as the 1st level pillars.

Step 3: Placing of DC Motors and sensors at the robot base

During this stage, most of the assembly will be done at the robot base. This stage focuses mainly on the installation of DC motors with the required mechanical parts, which are shaft coupling and cylindrical shaft, together with the rubber wheels. Before any drilling is started, the markings are done on the base of the board which is for placement of DC motor platform. For the connection between the platform and the robot base, 2 screws of dimension M4*40 are used, whereas 4 screws of dimension M3*10 are used to connect the DC Motor bracket and the motor platform. Table 8 below shows the list of the required components required to assembly the whole mechanism:

Table 8: Lists of Components required for the assembly of the wheel mechanism

Required Components	
DC Motor	
DC Motor Bracket	
6mm to 8mm shaft coupling	

8mm shaft	
Hex coupling for wheel	
Wheel	

Figure 69: Placement of DC Motor and the required mechanical components

Figure 70: Placement of Ultrasonic Sensor at the base

In Figure 69 above, the DC motor is secured on the platform first before the entire assembly is being screwed into the robot base. In Figure 70 above, the sensor holder is secured to the robot base using 4 pan head screws of dimension M3*25.

Step 4: Placing of top cover and the 4 covers

The final stage is mostly about the covering of robot skeleton chassis using the aluminium composite panel. For the top base, aluminium panel of dimension 30cm by 30cm is cut and secured to the top using 8 screws of dimension M4*25. Figure 71 below shows the placing of top cover after assembling the 4 pillars for the 2nd compartment:

Figure 71: Placing of Top Cover with the addition of the ultrasonic sensor holder on top

For the front cover, two separate panels are cut and covered the chassis. This is because the bottom compartment consists of IR sensor holders connected to the cover, and the upper compartment consists of the Raspberry Pi camera attached at the wall of the cover. For the back cover, 1 single panel of dimension 30cm by 35cm will be connected with the aluminium hollow bar using 4 screws of dimension M4*40. Figure 72 below shows how the aluminium panels are used to cover the front part.

Figure 72: Placing 2 separate covers in front of the robot

The reason why 2 separate panels are used to cover the front part of robot is to reduce the error of drilling when the measurements are made. When marking one drilling point, an alignment error of about 1 mm is made, hence the more the number of screws connected for each panel, the higher the alignment error, which causes the aluminium panel to unable to fit in properly.

After placing the front cover, the IR sensor holders are attached on the wall cover. Each IR sensor holders are connected with an extension so that the distance between the IR sensor and the ground is between 2 cm and 4 cm. For the connection between each sensor holder and the extension, 2 screws of dimension M3*15 are used, whereas screws of dimension M3*20 are used to connect the extension to the front cover of robot. The placing of IR sensors in front of robot can be seen in Figure 73 below:

Figure 73: Placing of 3 IR sensors in front of robot

Figure 74: Isometric view of the prototype before covering the sides.

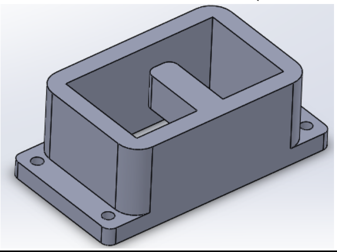
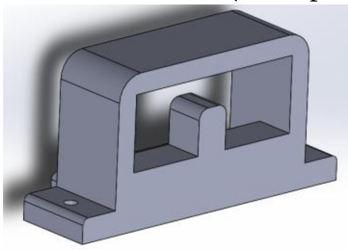
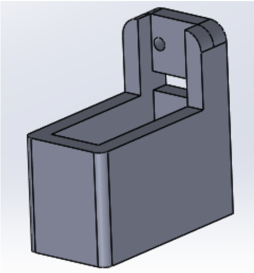
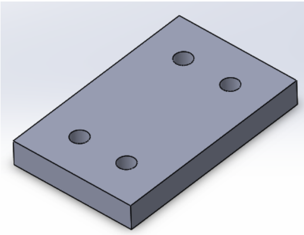
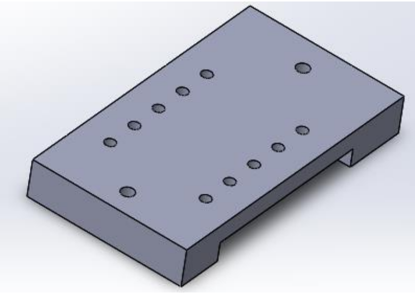
In Figure 74 above, during the testing and calibration of robot, both sides are left opened first in case any removing of the connectors or adjustment of the position of Raspberry Pi 4B is carried out.

For the covering of the robot chassis, it will only be done right after the testing and calibration has been completed.

3D-Printing of Required Parts (Week 2-3)

On top of building and assembling the prototype, there are some parts which need to be 3D-printed, particularly sensor holders and DC motor platform stands. Table 9 shows the 3D-printed parts used and their uses.

Table 9: List of 3D-Printed Parts and their Functions

3D-Printed Parts	Uses
Ultrasonic Sensor Holder (Robot Base) 	Holds the ultrasonic sensor at the robot base in position.
Ultrasonic Sensor Holder (On top of Robot) 	Holds the both ultrasonic sensors on top of the robot, which is used in obstacle detection.
IR Sensor Holder 	Holds the IR sensors in position, and to ensure that the IR sensors are pointing perpendicularly to the ground.
IR Sensor Extend 	Extend the IR sensor from the robot chassis, so that the distance between the IR sensor and the ground is between 2-3cm (optimal distance)
DC Motor Platform 	Support the motor bracket which holds the DC motor in position.

The following diagrams (Figures 75-78) show the list of 3D-printed printed out and their locations placed at:

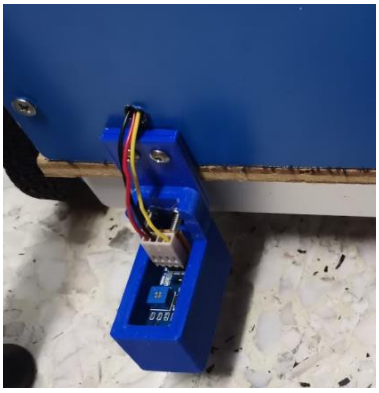


Figure 75: IR Sensor Holder and Extension Holder (Bottom front of the robot)

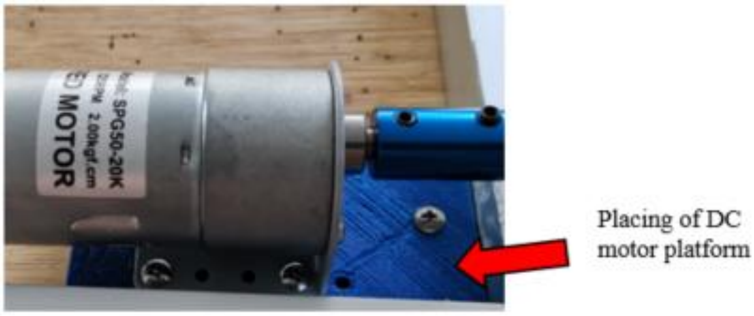


Figure 76: Placement of DC Motor Platform underneath the robot base

Figure 77: Placement of Ultrasonic Sensor Holder (Bottom of Robot Base)

Figure 78: Placement of Ultrasonic Sensor Holder (Top of Robot)

Logbook Phase 3 (Week 4 – Week 6)

Designing and Building of Electronic Circuit

After finishing the mechanical task, it is followed by designing and building of electronic circuit. Beside the main circuit which is the GPIO circuit, the other 2 sub-circuits are:

- ADC Circuit
- DC Motor Driver Circuit

The schematic diagrams for the ADC circuit and the DC Motor Driver circuit are shown in Figures 79 and 80 below:

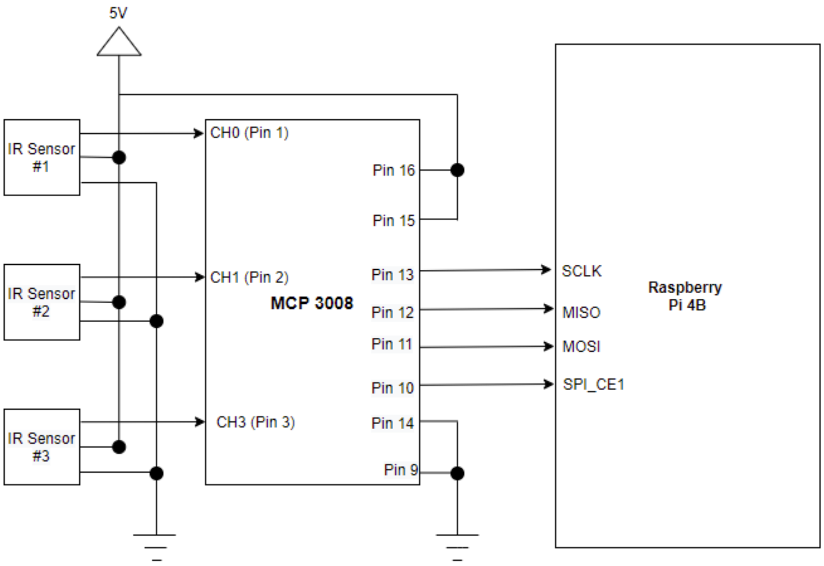


Figure 79: Schematic Diagram of ADC Circuit

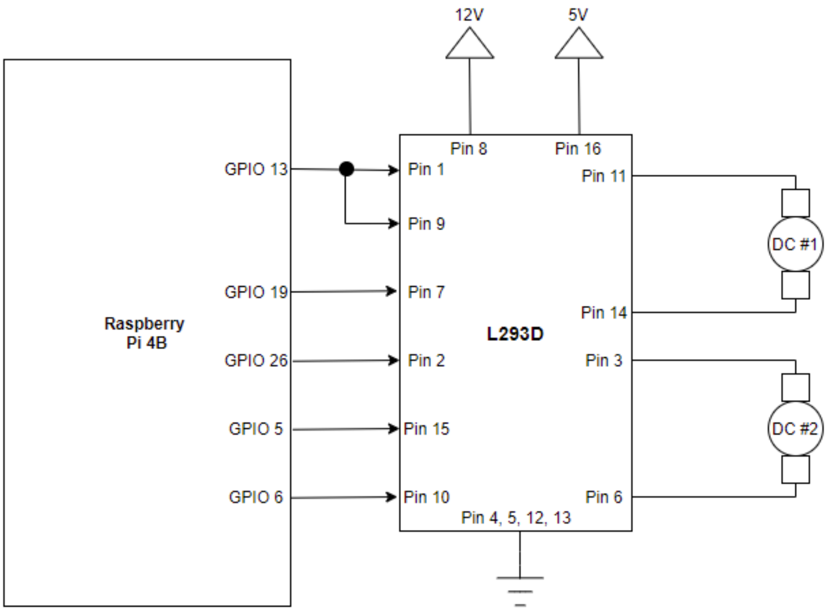


Figure 80: Schematic Diagram of DC Motor Driver, L293D Circuit

For the connection between the Raspberry Pi 4B and the GPIO extension board, a 40 female-pin extension cable is connected, as shown in Figure 81 below.

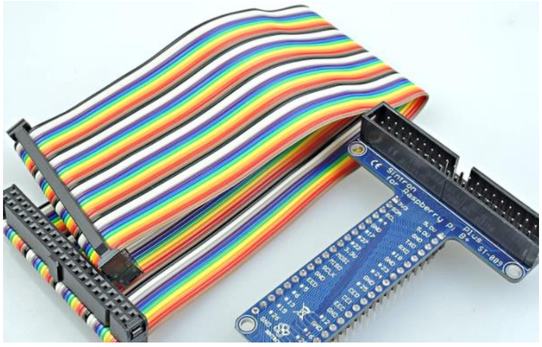


Figure 81: 40 female-pin extension cable(left) and GPIO Extension board

The GPIO extension board is soldered to the vero stripped board indirectly by soldering the 20-pin header into the board first, so that the extension board can be plugged out for troubleshooting purpose, shown in Figure 82 below:

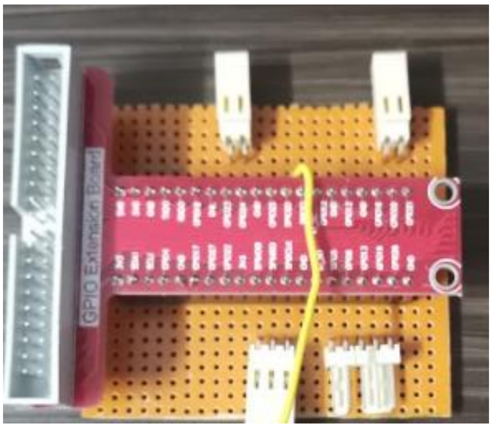


Figure 82: Inserting of GPIO Extension board into the 20-pin headers which are already soldered into the board

Figure 83 below shows the DC Motor driver circuit which have been soldered and wired as well:

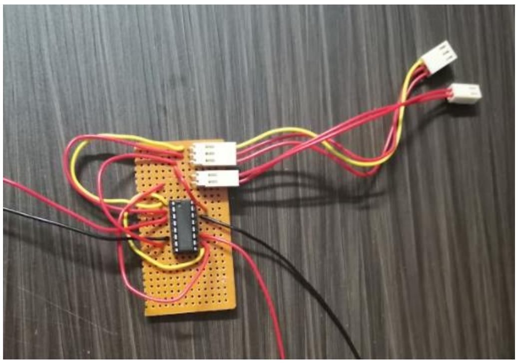


Figure 83: Soldered Circuit for DC Motor Driver circuit

After finishing soldering the circuits for ADC and the DC motor driver, the internal wirings can be carried out by crimping the wires, followed by inserting the crimped wire into the pin header socket, so that connection can be created between the sensors and the GPIO board. Figure 84 in the next page shows the internal robot wirings which have been carried out:

Figure 84: Wiring Diagram for IR sensor (left) and DC motors (right)

On top of carrying out soldering and wiring task, the power supply circuit needs to be designed so that the robot can be powered by an external portable battery voltage source. The block diagram of the power supply is shown in Figure 85 below:

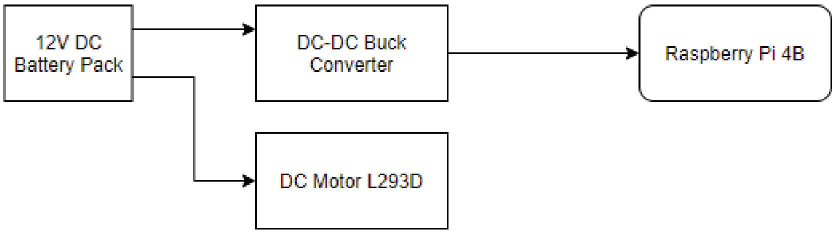


Figure 85: Block Diagram of the Power Supply Circuit

To suit the input requirements of Raspberry Pi 4B, the output voltage of the DC-DC buck converter is set to 5.2 V and the output current is set to 3.0 A by shorting the output terminal with a wire and then the potentiometer knob is turned until the 7-Segment LEDs indicate 3.0 A, the illustrations can be shown in Figure 86 below:

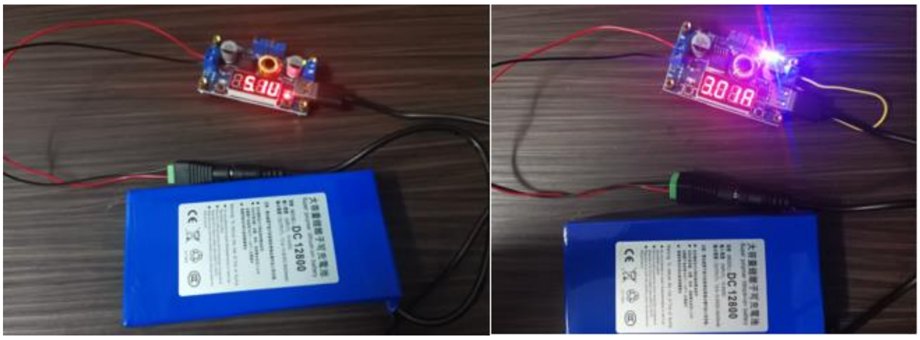


Figure 86: Adjusting output voltage (left) and adjusting output current(right) of the DC-DC Buck Converter

Logbook (Final Phase – Week 7 – Tuition Week)

Calculation and Setting of Camera Tilting Angle

Consider the illustration in Figure 87 below (social distancing):

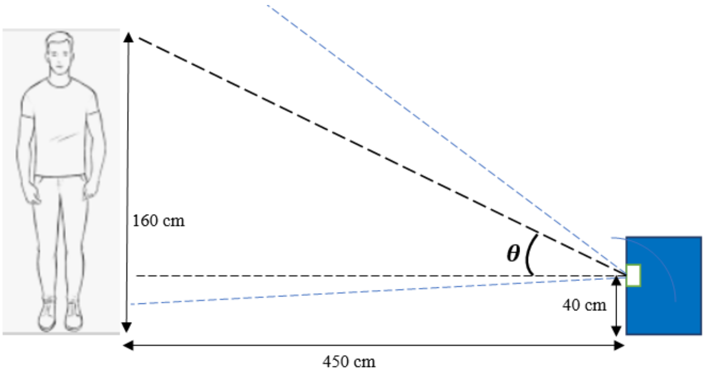


Figure 87: Illustration of the range of social distancing detection

Based on the Figure 87 above, the angle can be determined using Trigonometry Ratio formula:

$$\tan\theta = \frac{160 - 40}{450}$$

$$\theta_{\min\,(social\ distancing)} = 14.93°$$

If the distance is shortened to 250 cm:

$$\tan\theta = \frac{160 - 40}{250}$$

$$\theta_{\max\,(social\ distancing)} = 25.64°$$

Based on the calculation, for social distancing detection, the minimum distance between the citizens and the robot is 250 cm.

For face mask detection, the maximum distance which the mask can be detected is 170 cm, as shown in Figure 88 below:

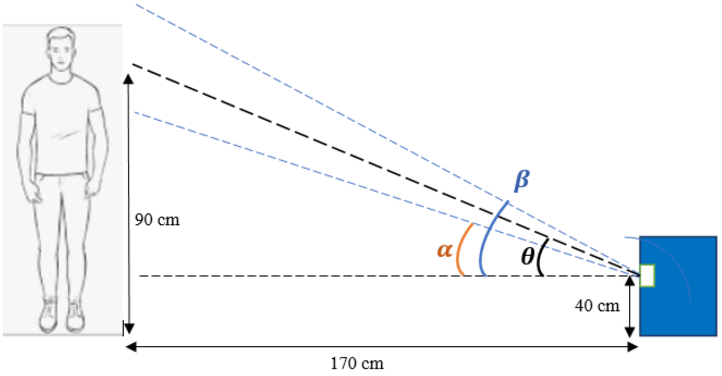


Figure 88: Illustration of the range of face mask detection

$$\tan\theta = \frac{90-40}{170}$$
$$\theta_{\min\,(mask)} = 16.39°, \beta = 16.39 + 24.4 = 40.79°$$
$$Let\ the\ maximum\ height\ of\ the\ person\ be\ h$$
$$\tan 40.79 = \frac{h-40}{170}$$
$$h = 186.7\ cm\ for\ the\ case\ when\ distance = 170cm$$

When the distance is reduced to 120 cm:

$$\tan\theta = \frac{90-40}{120}$$
$$\theta_{\max\,(mask)} = 22.62°, \beta = 22.62 + 24.4 = 47.02°$$
$$Let\ the\ maximum\ height\ of\ the\ person\ be\ h$$
$$\tan 47.02 = \frac{h-40}{120}$$
$$h = 168.8cm\ for\ the\ case\ when\ distance = 120cm$$

Based on the calculations, the suitable tilting angle that can be implemented is 20° as at this angle the camera is able to detect mask wearing and social distancing at a suitable distance. However, there will be a limitation, which is the maximum height of the detectable person is 187 cm when the robot is 170 cm away from the person, and the maximum height of the detectable person is 168.8 cm when the robot is 120 cm away from the person.

For the camera holder, the STL file for the 3D modelling of the pi camera can be downloaded from the Cytron official website. Where the STL file can be used to 3D-print the camera holder. Figure 89 below shows the parts which has been 3D-printed out:

Figure 89: 3D-Printed camera holder

Creating Flowcharts

Before writing programs, flowcharts are drawn first. Figures 90-94 below show the flowcharts that are created:

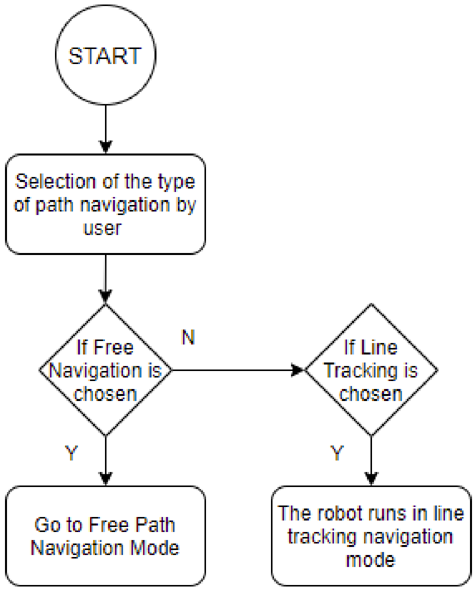


Figure 90: Flowchart for Selection of Path Navigation by the user

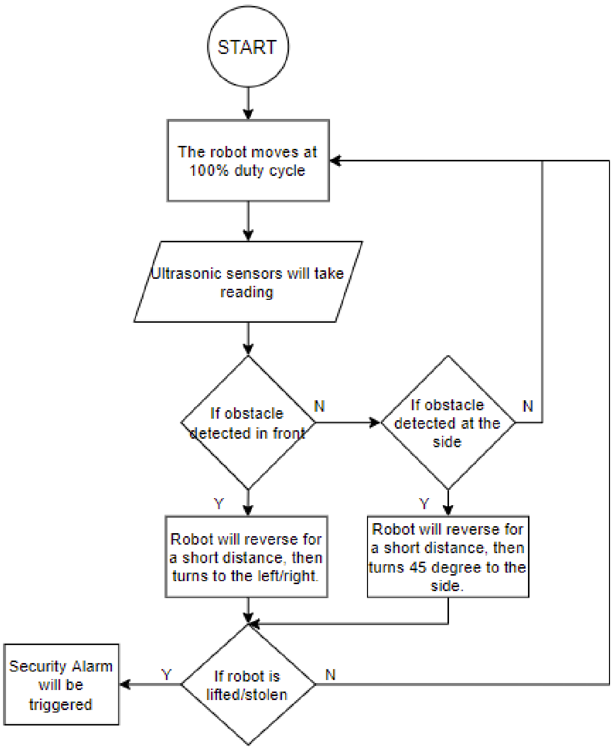


Figure 91: Flowchart for Free Navigation of Robot

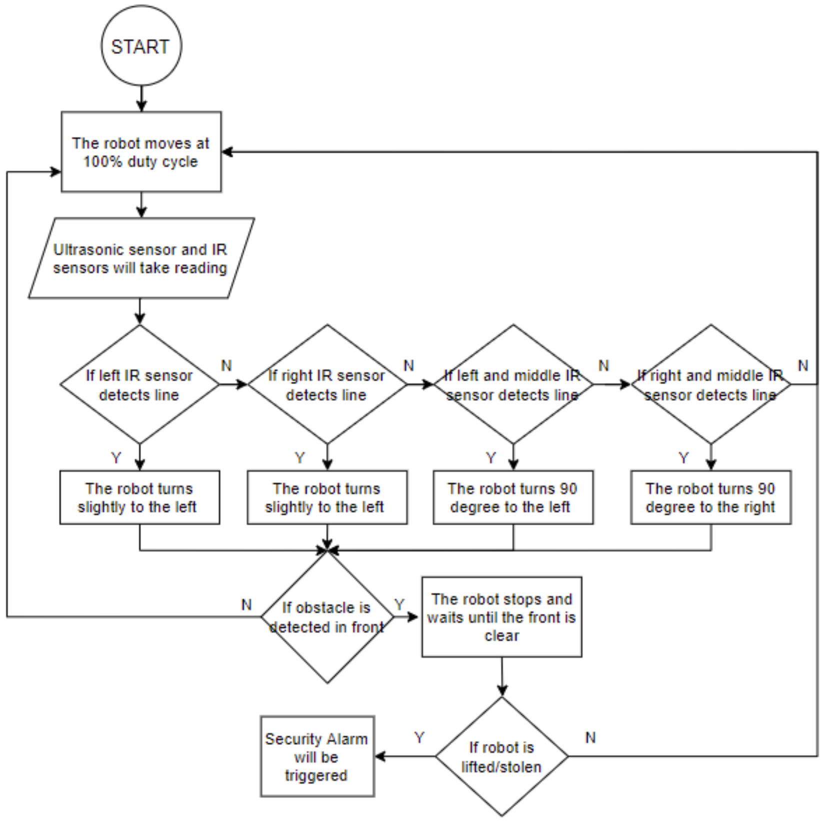


Figure 92: Flowchart for Line Tracking Navigation of Robot

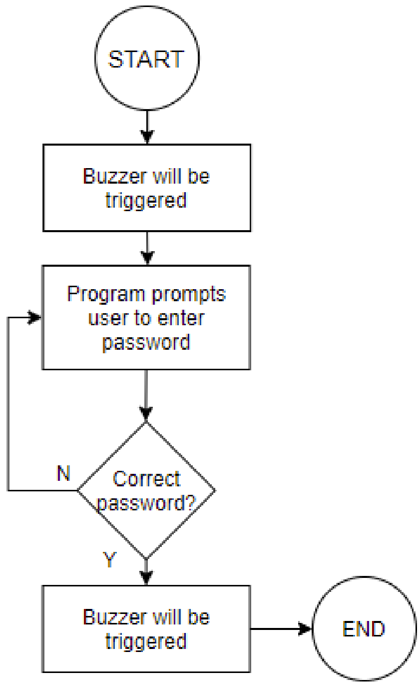


Figure 93: Flowchart for Security Implementation

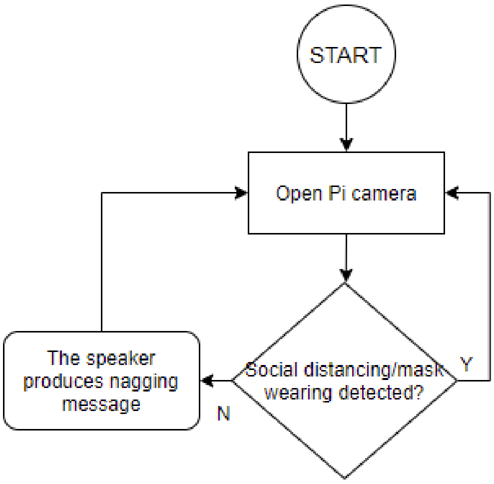


Figure 94: Flowchart for Mask Wearing/Social Distancing detection

Training of AI Model for Face Mask Detection

For the mask detection, AI model will be trained so that the robot can identify the absence of mask wearing of a person. Sample of 1000 images for both categories (with mask and without mask) will be used as the dataset, so that the camera is able to detect masks of different colours. Figure 95 below shows the sample datasets used for both categories (with mask and without mask):

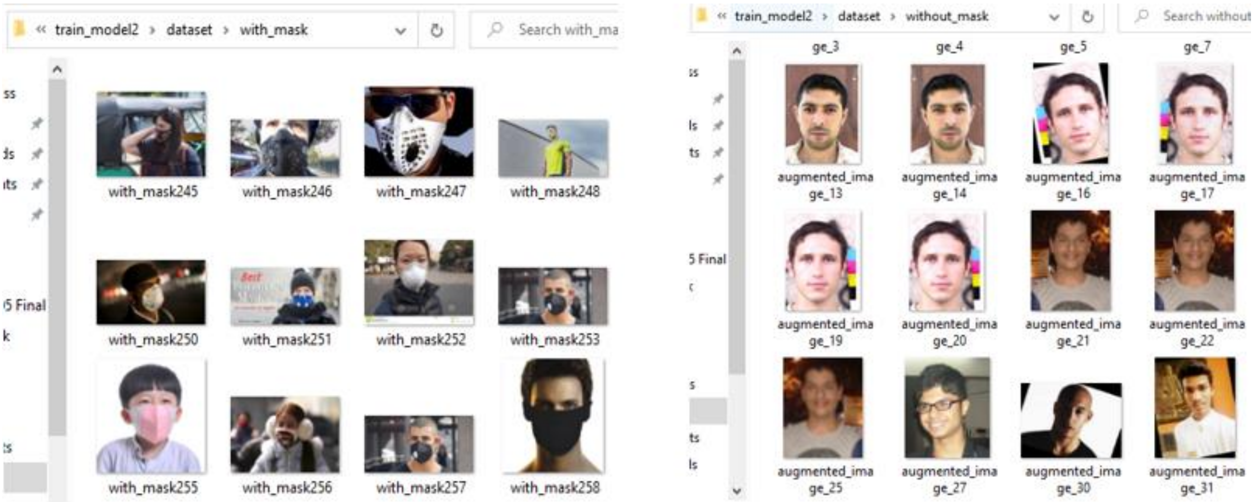


Figure 95: Sample Images from both dataset of different categories

After loading sufficient images into the dataset folder above, the model can be trained by setting the Epoch to 20, initial learning rate to be, and the batch size to be. After that, it will take around half an hour to 1 hour to train the AI model completely, before another program is run to interface the pi camera for face mask detection. Figure 96 below shows the screenshot from the command prompt when the model is being trained in progress:

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applicatio
ns/mobilenet_v2/mobilenet_v2_weights_tf_dim_ordering_tf_kernels_1.0_224_no_top.h
5
9412608/9406464 [==============================] - 8s 1us/step
[INFO] compiling model...
[INFO] training head...
2021-05-08 22:11:35.900021: I tensorflow/compiler/mlir/mlir_graph_optimization_p
ass.cc:116] None of the MLIR optimization passes are enabled (registered 2)
2021-05-08 22:11:35.901423: W tensorflow/core/platform/profile_utils/cpu_utils.c
c:116] Failed to find bogomips or clock in /proc/cpuinfo; cannot determine CPU f
requency
Epoch 1/20
25/25 [==============================] - 169s 6s/step - loss: 0.7742 - accuracy:
 0.6246 - val_loss: 0.4277 - val_accuracy: 0.9412
Epoch 2/20
25/25 [==============================] - 142s 6s/step - loss: 0.5328 - accuracy:
 0.7623 - val_loss: 0.3208 - val_accuracy: 0.9559
Epoch 3/20
25/25 [==============================] - 142s 6s/step - loss: 0.4249 - accuracy:
 0.8506 - val_loss: 0.2566 - val_accuracy: 0.9706
Epoch 4/20
25/25 [==============================] - 142s 6s/step - loss: 0.3449 - accuracy:
 0.9022 - val_loss: 0.2327 - val_accuracy: 0.9559
25/25 [==============================] - 142s 6s/step - loss: 0.3129 - accuracy:
 0.9091 - val_loss: 0.1855 - val_accuracy: 0.9804 - loss: 0.3144 - accuracy: 0.9
Epoch 6/20
25/25 [==============================] - 143s 6s/step - loss: 0.2854 - accuracy:
 0.9187 - val_loss: 0.1759 - val_accuracy: 0.9804
```

Figure 96: Screenshot from the Command Prompt

After finishing the training process, a graph of the losses/accuracy vs the number of epochs will be plotted as shown in Figure 97 below:

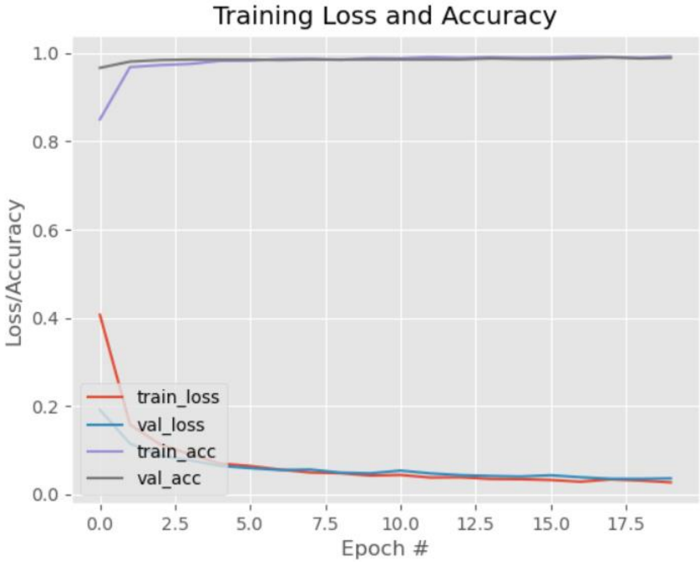


Figure 97: Graph of Losses/Accuracy vs the Number of Epoch

Based on the graph above, the higher the number of epoch, the lower the losses thus resulting in higher accuracy. However, the epoch should not be set too high as it may overtrain the AI model. Figure 98 and 99 shows the results from the camera for presence and absence of mask detection respectively:

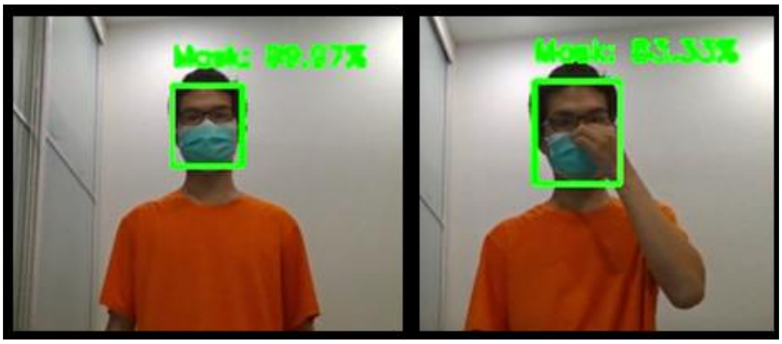


Figure 98: With Mask

Figure 99: Without Mask

Meeting Minutes

Date	Discussions	Follow-Ups
12/3/2021	• Student presented the tasks being carried out during the last semester break to supervisor.	• Supervisor advised that student need to document the tasks carried out during the semester break as well into the report.
26/3/2021	• Student showed the CAD Drawings diagram to supervisor, in which the CAD model are the parts which will be 3D-printed out. • Student presented some photos of the assembled prototype(without covering it yet) to supervisor.	• Supervisor advised student to document each CAD drawing design into report, like explaining the design considerations of why this dimension of the 3D-printed part is used. • Start doing electronic section.
9/4/2021	• Student showed the 3D-printed parts to supervisor, as well as the sensors which have been soldered and placed inside the IR sensor holder (3D-printed). • Student showed the power supply circuit hardware to supervisor, which consists of battery pack, voltage converter and USB-to-Type C cable.	• Supervisor is satisfied with the 3D-parts being printed out, as well as the robot appearance. • Supervisor advised the student to document the power supply circuit into the report as well.
23/4/2021	• Student presented some photos of the soldered circuit boards and wirings to supervisor. • Student also presented the created FYP2 final report template to supervisor to check for any amendments needed.	• Supervisor advised the student to include the headings and subheadings of each section of the robot.
30/4/2021	• Student showed a video of the robot moving in a straight line to supervisor.	• Supervisor advised the student to create another video of the robot moving freely involved with turning and obstacle involved. • Supervisor also suggested that the path navigation can be of dual mode, in which the path navigation method can be chosen by user (either line sensing of free navigation)
7/5/2021	• Student showed a video of the robot roaming around to supervisor. • Student also addressed the issue of the motor not working properly, which causes the robot motion to be jerking.	• Supervisor commented that the turning of the robot is a little but jerking. • Supervisor suggested that the student replace the original wire with thicker wire, as thicker wire has lower resistance, which

		results in higher current drawn to the DC Motor.
12/5/2021	• Student addressed the lagging of the video capturing from Pi Camera viewed from VNC Viewer to supervisor. • Student showed the final hardware setup inside the robot assembly.	• Supervisor commented about the nagging message function of the speaker of the robot. • Supervisor suggested that the issue for the 2 programs to be run simultaneously can be considered as a limitation.
21/5/2021	• Student presented the written report (excluding conclusion and reference) to supervisor. • Student showed a video of the wall detection and the face mask detection camera view from VNC Viewer.	• Supervisor gave comments to the report, suggesting that each figures and tables must have a description statement preceding it. For example, “Figure…below shows the function of the robot…” • Supervisor is satisfied with the videos recorded by the student, and advise the student to compile all the videos of each feature of the robot into 1 single video file.
28/5/2021	• Student show the presentation slides to supervisor. • Student presented all the documents prepared (Report and Research Paper) to supervisor.	• Supervisor provided comments for the student to amend the presentation slides. • Supervisor also advised the student to make sure that the text is justified on the left and on the right as well.