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A Bluetooth and Vision Controlled Automatic Guided Vehicle

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Abstract: The aim of this project is to construct a Bluetooth (2.4GHz) and vision controlled auto guided vehicle (AGV) for use during the COVID-19 pandemic. The auto guided vehicle can be maneuvered by using an application in mobile phone or auto guided function. The auto guided function of the vehicle is following the label that is affixed on the user. Bluetooth communication was applied to control the AGV at a maximum distance of 10 m. The auto guided vehicle can carry a maximum of 10 kg load. The vision system applied could track and follow the human movement affixed with a label. The best following distance of the AGV developed is within 80cm and the angle of detection is 55°. The auto guided vehicle can reduce the risk of the user in contacting the AGV and hence, minimising the risk of virus infection. It also helps the senior user to save energy in pushing the heavy cart.

Keywords: Bluetooth controlled, automatic guided vehicle

1. Introduction

From December 2019, people from all walks of life have begun to face the new disease COVID-19 and adapting to new norms of life. COVID-19 is a disease that occurred in Wuhan, China at the end of 2019. This horrible disease spread widely and quickly. From the World Health Organization (WHO) official website, it shows the latest cumulative cases of COVID-19 until 16 December 2021 are 271,376,643 confirmed cases and 5,324,969 deaths [1]. According to the World Health Organization (WHO), COVID-19 is a contagious disease that will spread easily between humans and is caused by SARS-CoV-2 virus [2]. Virus transmission has two different kinds such as direct or indirect [3]. Direct virus transmission is deposited on persons while indirect is deposited on objects. Direct virus transmission occurs by oral fluid droplets, mainly airborne through coughs, sneezes, breaths, speaks and so on [4]. The fluid droplets not only can directly infect a person, it also will stay on the object. When the infected person coughs or sneezes, the droplet will fall on the surrounding objects such as tables, cabinets, chairs and others [5]. The COVID-19 virus can survive on the surface of objects for 28 days at ambient temperature and humidity [6]. When people touch the contaminated object, after that touch their eyes, nose or mouth it will cause them to become infected. In this COVID-19 pandemic, every person should change their lifestyle to prevent the spreading of the virus.

Nowadays, a lot of sectors can use a high technology robot to reduce the risk of spreading the virus. Khan et al. [7] research on using robotics technology in the healthcare sector. In the research, robotics technology can be used in different kinds of applications in healthcare such as nurse robots, ambulance robots, serving robots, cleaning robots, disinfection robots and so on. Shen et al. [8] research on different kinds of robots used in COVID-19 pandemic. In the research, many types of robots were invented to serve in different types of areas such as disinfection, diagnosis, screening, logistics, manufacturing and so on. So, using a robot in a pandemic can be very effective to reduce the risk of getting infected.

With the rapid development of technology, there are a lot of auto guided cars, robots or trolleys invented to use in different sectors. Samidi et al. [9] designed an intelligent following sensor shopping cart using a colour detection mechanism. The working mechanism is using an application to detect colour and will send the selected colour to the microcontroller of the shopping cart via Bluetooth. After that, the shopping cart will follow that object colour and can avoid obstacles using ultrasonic sensors. The disadvantages of this design are the colour detection requires a high-

resolution camera to reduce the tolerance and the colour detection will be affected by the light intensity of the surrounding. Tayal et al. [10] designed a line follower robot using infra-red(IR) sensors to follow the given path. The line follower robot tested on a white surface and followed the black colour line. The colour difference between line and surface should be strongly different. This line follower robot can only follow the path and will not follow the user or can be controlled by the user. Roopesh et al. [11] proposed a smart tracking automaton using ultrasonic sensors and Arduino. The automaton will always follow the person in front using an ultrasonic sensor. The sound waves transmitted by the ultrasonic sensor will be bounced back by the obstacle and received by it. The time transmitted and received by the ultrasonic sensor will let the automaton know the distance of the person in front. So, the automaton will move forward or backward depending on the distance. This smart tracking automaton has an obvious disadvantage is the user must stand in front of the automaton to let ultrasonic sensors sense the user. Besides that, if something moves between the user and the automaton, it will have the probability of following the wrong person or object. In this project, designing a Bluetooth and vision controlled automatic guided vehicle (AGV) will reduce users from touching the vehicle and will reduce the risk of getting infected in the working area. The AGV can carry load and can be used in hospitals, office areas, industry, school, supermarket and so on. Fig. 1 shows the model graphic of the AGV.
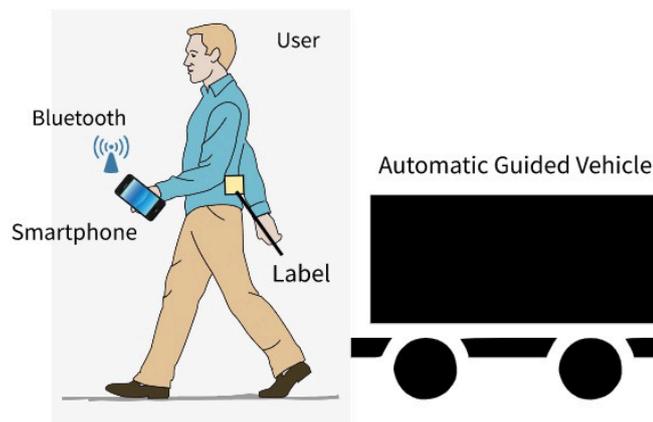

Fig. 1 - Model graphic of the automatic guided vehicle

The objective of this study is to design a Bluetooth and vision controlled automatic guided vehicle (AGV) to reduce the users contact with the vehicle. Next, it needs to design an algorithm to control the system of the automatic guided vehicle. Lastly, it needs to construct and test the mechatronics system of the automatic guided vehicle that can carry a maximum of 10 kg load.

The scopes of this project are programming the microcontroller using C++ language in Arduino Integrated Design Environment (IDE) software. The AGV is using Arduino MEGA as the microcontroller. After coding, the microcontroller will control the wheels direction, auto guided function and Bluetooth module of the robot. Next, development of control APP. It is using MIT App Inventor to design an application to control the vehicle. The application is connected with the vehicle using a Bluetooth connection. The user can select automatic guided mode or Bluetooth control mode in the application. In building the prototype of an automatic guided vehicle, it is using SelfCAD software to draw the 3D drawing of the AGV. The materials to build the vehicle are PVC pipes. The hardware electronic components are mentioned in the materials part.

2. Methodology

The procedures to construct the AGV that can function with automatic guided function and Bluetooth control using mobile application described in this part.

2.1 Materials

To build the auto guided function, it is using HuskyLens to act as the AI machine vision sensor to sense the label on the user and follow the user. The Bluetooth control function is using the Bluetooth module HC-05 connected with the smartphone application. The materials to build the frame of AGV are PVC tubes. The hardware electronic components used in this AGV as stated below:
- HuskyLens
- DC motors
- MDD10A motor driver
- Arduino MEGA 2560
- 12V 7.2AH sealed lead acid battery
- HC-05 Bluetooth module

• 10400mAH power bank

The MDD10A motor driver used to control the DC motors. It can control the rotational speed and direction of two DC motors at the same time. The microcontroller used for this AGV is Arduino MEGA2560. The Arduino board is powered by the 10400mAH power bank. The 12V 7.2AH sealed lead acid battery is the power supply of DC motors and connected to the motor driver. Fig. 2 shows the block diagram of the automatic guided vehicle.
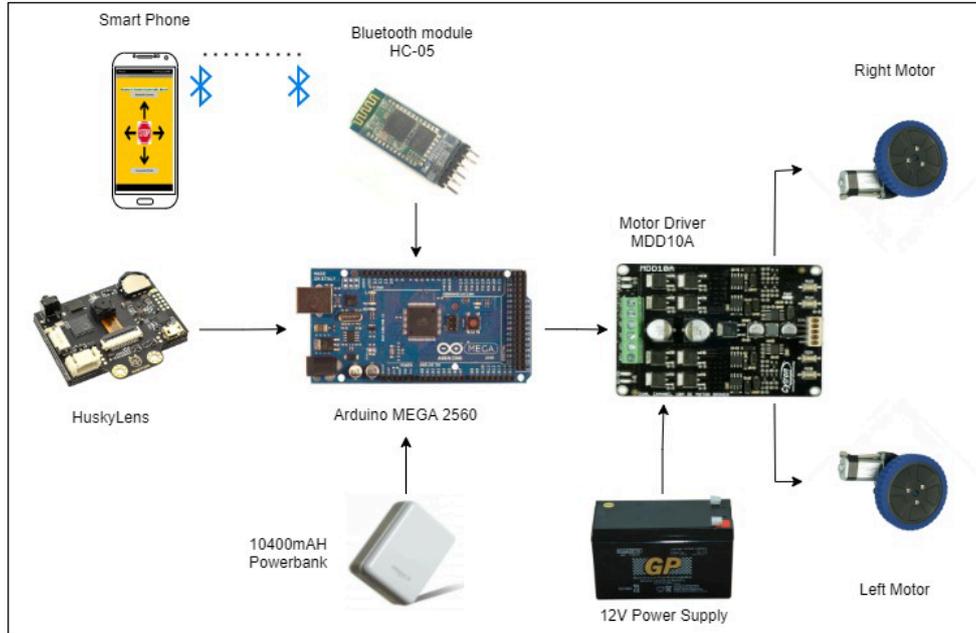

Fig. 2 - Block diagram of automatic guided vehicle

2.2 Flowchart of AGV

The flowchart of the AGV is shown in Fig. 3. The automatic guided vehicle system starts with connecting the Bluetooth with the application. After connecting the Bluetooth, the user can select the button in the application to control the AGV. If the forward button is pressed, the app will send letter 'F' to the microcontroller and the AGV will move forward. If the left button is pressed, the app will send letter 'L' to the microcontroller and the AGV will turn left. If the right button is pressed, the app will send letter 'R' to the microcontroller and the AGV will turn right. If the backward button is pressed, the app will send letter 'B' to the microcontroller and the AGV will move backward. If the stop button is pressed, the app will send letter 'S' to the microcontroller and the AGV will stop and not move. When the auto guided mode button is pressed, the app will send letter 'A' to the microcontroller and the AGV will start to follow the label. When HuskyLens senses the object x-axis coordinate is less than 90, the AGV will turn left. When HuskyLens senses the object x-axis coordinate is greater than 230, the AGV will turn right. When HuskyLens senses the object frame height is less than 40, the AGV will move forward. When HuskyLens senses the object frame height is greater than 80, the AGV will move backward. If there is no label detected, the AGV will stop and not move. The AGV will not follow the Bluetooth controlled system when the auto guided mode button is pressed. This can avoid the conflict if the Bluetooth control is turning left instruction and the label is moving right instruction.

Fig. 3 - Flowchart of automatic guided vehicle

2.3 Setting the HuskyLens

In the HuskyLens, it contains seven built-in functions such as face recognition, object tracking, object recognition, line tracking, colour recognition, tag recognition and object classification [12]. In this automatic guided vehicle, it is using object tracking function to achieve auto guided function. The auto guided function of this vehicle is following the label that was learned by HuskyLens. Firstly, sliding the function button on HuskyLens until showing the object tracking function. Next, it just needs to let the frame target on the label and press the learning button. The HuskyLens will learn

the label and the frame will always follow the label. Fig. 4 shows the coordinate system of HuskyLens. At the centre point, the x-axis is 160 and y-axis is 120. The maximum of the x-axis is 320. The maximum of the y-axis is 240. To design an automatic guided robot, it needs this coordinate system to get the coordinate of the object. When the coordinate of the object is less than x-axis 160, which means the object is at the left side.
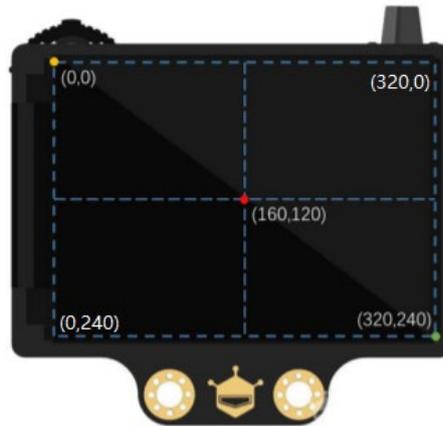

Fig. 4 - The coordinate system of HuskyLens

2.4 Designing the Application

To design the application to control the vehicle, MIT App Inventor is used to develop it. In the MIT App Inventor, it is just to place the buttons, labels and functions needed in the platform. For the coding part, it places a block code when Screen 1 is initialising that will set all the Bluetooth device address and name into the list picker. After picking the selection from the list picker, the Bluetooth will connect to that address and name. Next, there are six code blocks set for the buttons. When the forward button is clicked, the program will send text 'F' to the selected Bluetooth address. When the backward button is clicked, the program will send text 'B' to the selected Bluetooth address. When the stop button is clicked, the program will send text 'S' to the selected Bluetooth address. When the left button is clicked, the program will send text 'L' to the selected Bluetooth address. When the right button is clicked, the program will send text 'R' to the selected Bluetooth address. When the auto guided button is clicked, the program will send text 'A' to the selected Bluetooth address. That is all the block coding of the application. After designing, it just needs to click build application in the MIT App Inventor website. It will produce an android application package (APK) file or QR code to let users download the designed application. Fig. 5 shows the layout and blocks coding of the application.
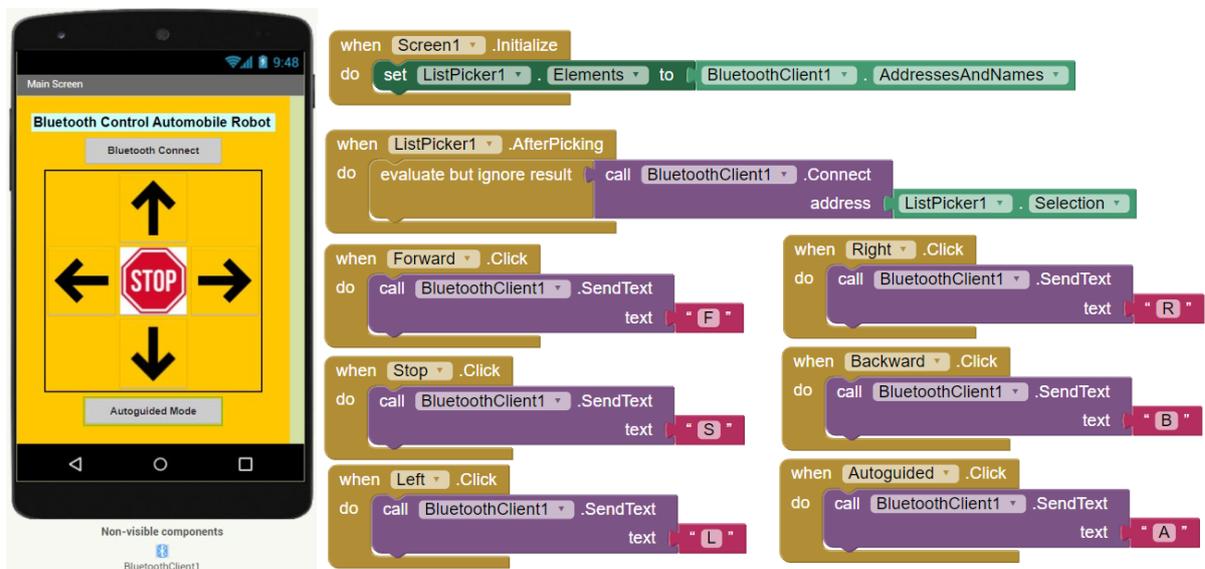

Fig. 5 - Layout and blocks coding of the application

2.5 Constructing the Hardware

Fig. 6 shows all the connections of the components used in the vehicle. The power supply of the Bluetooth module and HuskyLens is from the Arduino board. The power supply of the motor driver is connected to the 12V battery. The

microcontroller will receive data from the HuskyLens and Bluetooth module. The Bluetooth module transmitter and receiver pins are connected to pin0 and pin1 of the Arduino board. The HuskyLens is using I2C connection. So, the transmitter pin is connected with the SDA pin and receiver pin is connected with the SCL pin of the Arduino board. For the MDD10A motor driver connection, it connects PWM1 and DIR1 with the pin3 and pin4 of the Arduino board. Besides that, PWM2 and DIR2 are connected with pin9 and pin10 of the Arduino board. The output of the motor driver is connected with DC motors.
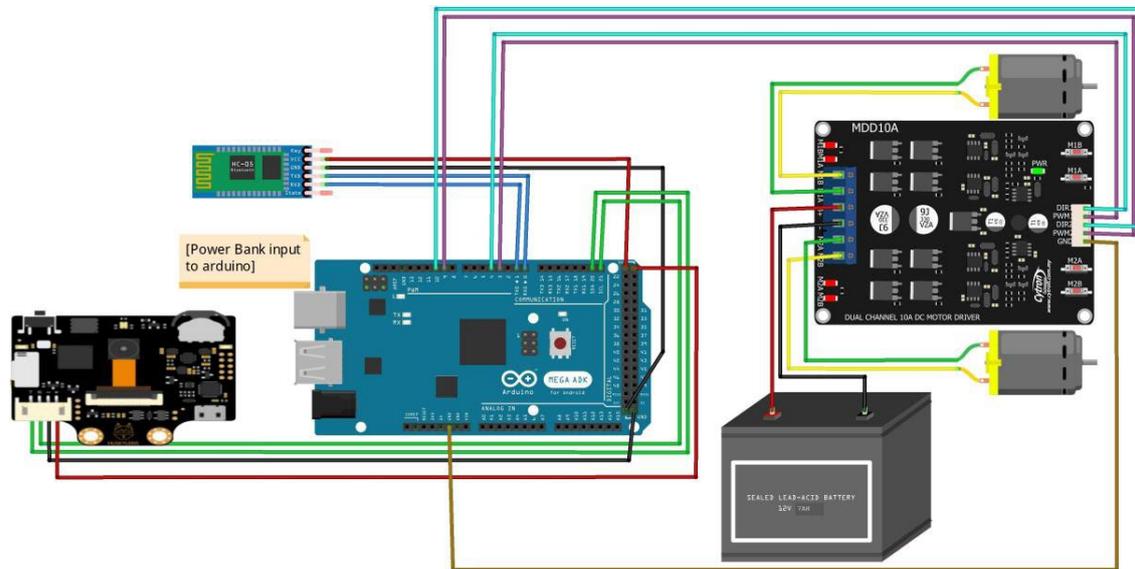

Fig. 6 - Layout and blocks coding of the application

Fig. 7 shows the 3D drawing of the auto guided vehicle. This vehicle has two layers. The upper layer is the place for carrying the load. The bottom layer has one box used to store the components of the electronic circuit. It will install four wheels at bottom. Two of the wheels will be connected with motors and can be controlled by a microcontroller to let the vehicle move forward, backward, left or right. The height is 90cm. The width is 50cm. The length is 60cm. The material to construct the body structure of AGV is 25mm Class 6 PVC pipe. The inner diameter of the PVC pipe is 25mm. The outside diameter is 33.4mm. Thickness of the wall of the Class 6 PVC pipe is 3.4mm. Class 6 able to withstand high pressure and weight. So, it is used to construct the body part of AGV to withstand the maximum 10kg load.
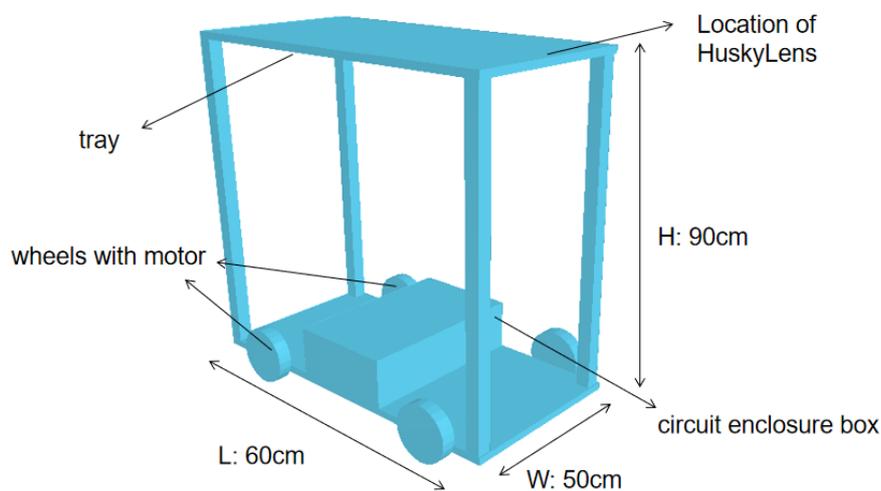

Fig. 7 - The 3D drawing of automatic guided vehicle

3. Results and Discussion

It shows the end product of the automatic guided vehicle in Fig. 8. At the upper tray, it has fixed the HuskyLens at the centre front of the AGV. The DC motors are fixed on the two sides of AGV using screws and nuts. At the lower tray, it has one circuit enclosure box to cover the electronic components used in this AGV. The height of this AGV is 94cm.

The width is 50cm and length is 60cm. Fig. 9 shows the electronic components used and are placed in the circuit enclosure box.
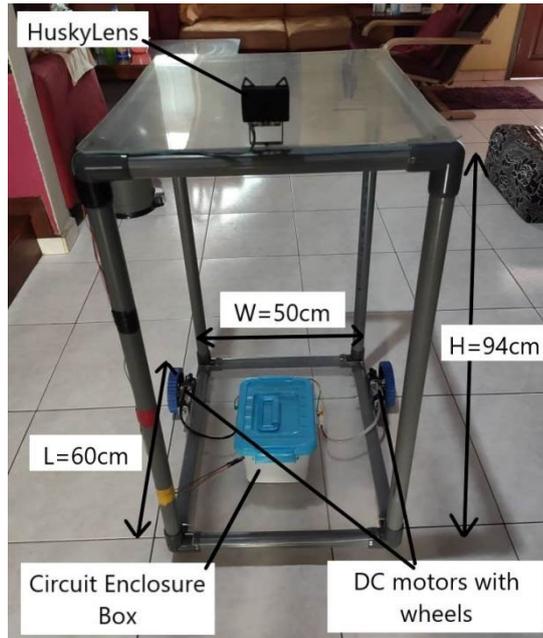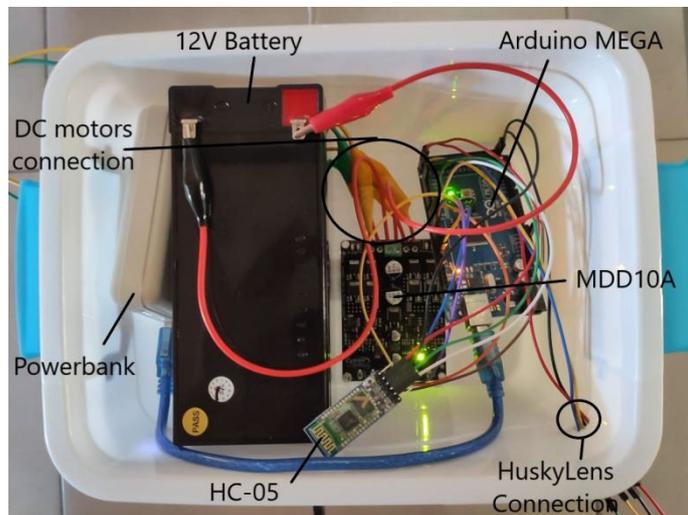

Fig. 8 - Automatic guided vehicle

Fig. 9 - The circuit enclosure box

3.1 Bluetooth Control Function

In this section, it shows the results of controlling the vehicle using the application through Bluetooth connection. All the buttons in the application functioning well and able to control the AGV nicely. Table 1 shows the results of controlling the AGV using the application via Bluetooth connection. When the forward button is pressed, the AGV will move forward. Both motors rotate clockwise direction. When the backward button is pressed, the AGV will move backward. Both motors rotate counter-clockwise direction. When the right button is pressed, the AGV will turn right. Left motor rotates clockwise direction and the right motor rotates counter-clockwise direction. When the left button is pressed, the AGV will turn left. Left motor rotates counter-clockwise direction and the right motor rotates clockwise direction. When the stop button is pressed, the AGV will stop.

Table 1 - Results of controlling the vehicle using the application via Bluetooth connection

Button pressed	Motor condition (Left)	Motor condition (Right)	AGV movement
Forward	Clockwise	Clockwise	Forward
Backward	Counter-clockwise	Counter-clockwise	Backward
Right	Clockwise	Counter-clockwise	Right
Left	Counter-clockwise	Clockwise	Left
Stop	Brake	Brake	Stop

Besides that, the functionality of different distances between the phone and the AGV was also tested in this section. The results are shown in Table 2. The AGV was tested in range 5 m, 7.5 m and 10 m. All the ranges tested are functional well. So, it can remotely control the movement of AGV from a distance of 10 m.

Table 2 - The functionality of different distance between the phone and the AGV

Distance between the phone with the AGV	Function
5 m	√
7.5 m	√
10 m	√

3.2 Automatic Guided Function

The output response is shown in Table 3. The rotation of the motors is correct and lets the AGV move properly. When the frame height is smaller than 40 and at centre position, the AGV will move forward. Both motors rotate clockwise direction. When the frame height is greater than 80 and at centre position, the AGV will move backward. Both motors rotate counter-clockwise direction. When the frame is at the right side position, the AGV will turn right. Left motor rotates clockwise direction and the right motor rotates counter-clockwise direction. When the frame is at the left side position, the AGV will turn left. Left motor rotates counter-clockwise direction and the right motor rotates clockwise direction. When the HuskyLens do not sense anything, the AGV will stop.

Table 3 - Results of controlling the AGV using the application via Bluetooth connection

Frame Position	Frame Height	Motor condition (Left)	Motor condition (Right)	AGV movement
Centre	Smaller than 40	Clockwise	Clockwise	Forward
Centre	Greater than 80	Counter-clockwise	Counter-clockwise	Backward
Right	-	Clockwise	Counter-clockwise	Right
Left	-	Counter-clockwise	Clockwise	Left
Missing	-	Brake	Brake	Stop

Besides that, the sight angle of the AGV had been measured as shown in Fig. 10. The maximum detection distance of the HuskyLens is 80cm. If the distance between the label and the AGV is longer than 80cm, the sensitivity of HuskyLens will be reduced. It causes the HuskyLens to sense the label unstable and inconsistent. The detection angle of HuskyLens is 55°. From the measurement, it can let the user know the angle sight of HuskyLens and the maximum distance of AGV to sense the label. The bright environment is needed for the working of HuskyLens. This is because a dark environment will let the HuskyLens cannot sense the label clearly.
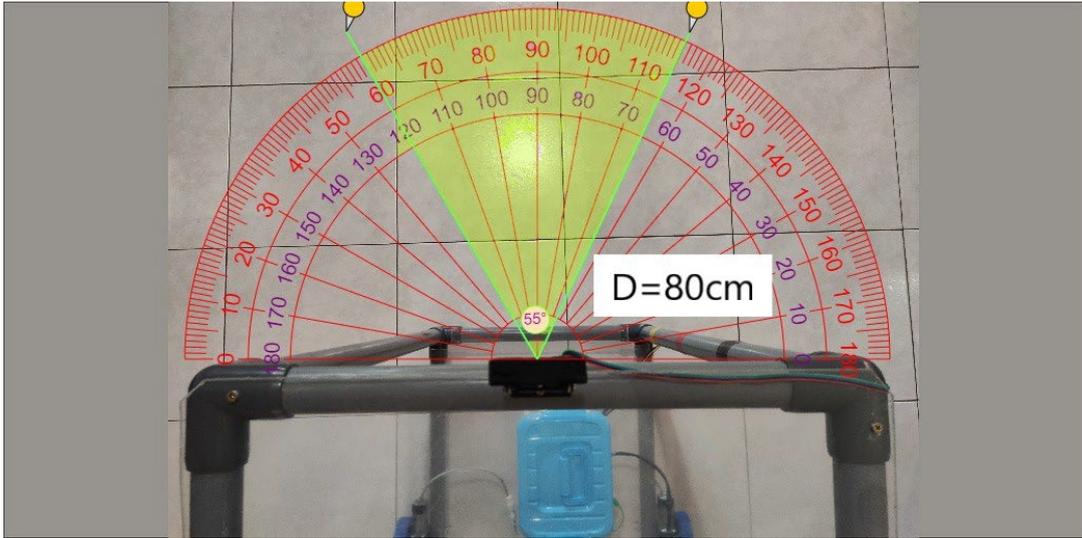
Fig. 10 - Map of detection of AGV

3.3 Testing the Maximum Load Bearing

In this section, the AGV is tested by carrying three different weights of loads. The loads that were used in this experiment are 5kg, 8kg and 10kg. The first testing is carrying a 5kg load. The AGV is able to carry 5kg load and work functioning well. Next, the AGV is tested to carry an 8kg load. When carrying an 8kg load, the AGV gets slower compared with carrying 5kg load. Lastly, the AGV is carrying a 10kg load. When carrying a 10kg load, the AGV gets slower compared with the lighter load. The heavier the load to be carried, the slower the speed of AGV. Table 4 shows the speed of AGV when carrying different load weights. Fig. 11 shows the graph of load weight versus speed of AGV.

Table 4 - The functionality of different weight of load carried by the AGV

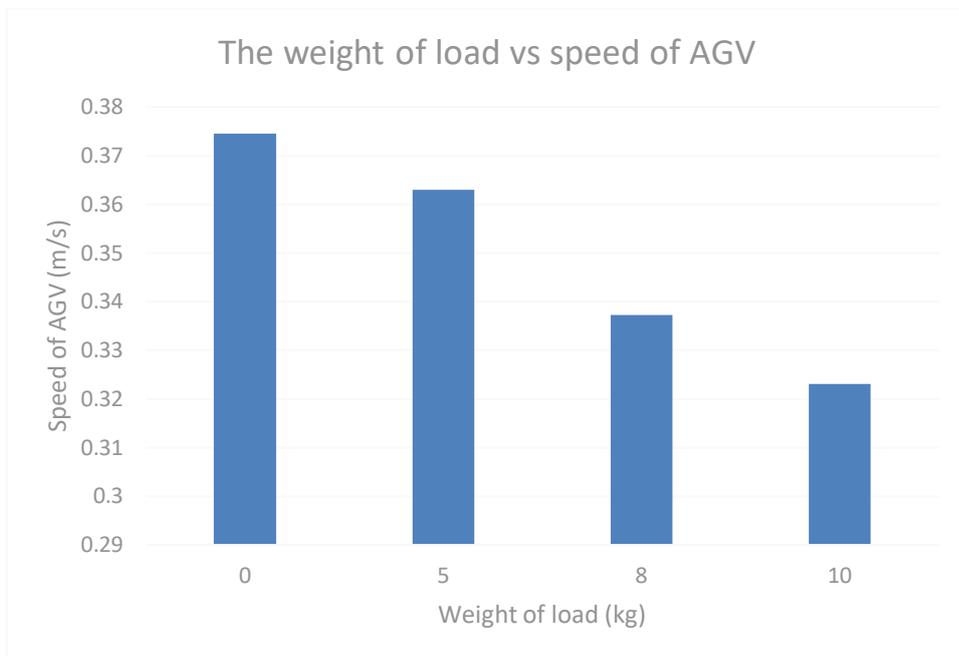| Load Weight (kg)	Distance (m)	Time (second)	Speed (m/s)
0	2	5.34	0.3745
5	2	5.51	0.3630
8	2	5.93	0.3373
10	2	6.19	0.3231

Fig. 11 - The graph of load weight versus speed of AGV

3.4 Comparing the Strength and Weakness of Two Functions

The strength of the Bluetooth control function is it can remote control the AGV using application. The Bluetooth control distance can be up to 10 m that was tested in the previous part. In contrast, the automatic guided function is limited by the distance and the detection angle of HuskyLens. The maximum distance is 80cm only. The angle of detection is 55° in front of the AGV. So, it will cause the user to always stay in the detection area. In addition, the strength of the automatic guided function is controlling the movement of AGV without any buttons. It will always follow the label that is affixed on the back of the user. On the other hand, the Bluetooth control function requires the user to be always keeping an eye on the AGV and clicking the button in application to move the AGV.

4. Conclusion

As a conclusion, this project had achieved the objective of designing a Bluetooth and vision controlled automatic guided vehicle that was able to reduce the users contact with the vehicle. The AGV can move without the contact of the user by using the application via Bluetooth connection. This AGV can be used in different kinds of working areas to reduce users from touching the vehicle and will reduce the risk of getting infected in the working area. For example, the working areas are hospitals, office areas, industry, school, supermarket and so on. Besides that, the objective of designing an algorithm to control the system of the AGV had been accomplished. The user is able to choose the function needed when in the working area. The functions are Bluetooth control function and automatic guided function. The Bluetooth control the vehicle had tested in range 5 m, 7.5 m and 10 m. All the ranges tested are functional well, so it can remote control the movement of AGV. Besides that, the auto guided function of the vehicle can follow the label that is affixed on the user. This function lets the user not need to push or pull the vehicle for moving purposes. The best following distance is within 80cm and the detection angle is 55°. Lastly, the third objective is realized because the AGV can carry a maximum 10 kg load. The AGV is tested in 5 kg, 8 kg and 10 kg loads. The AGV can carry all the loads and is functioning well. In the load bearing test, it can be concluded that the heavier the load to be carried, the slower the speed of AGV.

In the future work recommendation, the body frame of the AGV should be enhanced by adding more support to build a stronger body frame. Hence, it can withstand heavier loads. Besides that, it can add on more functions by using the built-in function of HuskyLens. For example, line tracking function, object tracking function and so on. Next, it needs to develop a more advanced application for the AGV. A more advanced application can ensure the stability of controlling the AGV. Furthermore, the AGV should add some safety precautions to prevent crashing on some things. For example, it can assemble with an ultrasonic sensor to sense the things in front to prevent crashing. When an ultrasonic sensor senses some things in front of the AGV, it will immediately stop the motors. In addition, the AGV can assemble two more motors for front wheels. It can increase the maximum load that can be carried by AGV.

Acknowledgement

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