Progress in Engineering Application and Technology Vol. 2 No. 2 (2021) 1155-1168
© Universiti Tun Hussein Onn Malaysia Publisher's Office

PEAT

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Optimizations of Autonomous Mobile Drawers for Industry

Sarah Nur Syahirah Sazali[1], Hazli Roslan[1]*, Suhaila Sari[2]

[1]Department of Electrical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

[2] Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia Pagoh, 86400, Batu Pahat, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2021.02.02.104
Received 29 August 2021; Accepted 07 October 2021; Available online 01 December 2021

Abstract: In the global industrial sector, robots are evolving rapidly from powerful stationary machines to a more complex mobile platform to meet a wider range of automation needs. One of the most innovative automation solutions to some of the problems faced in the industries are definitely the Autonomous Mobile Robots. Deploying Autonomous Mobile Robots in an industrial environment is not an unusual concept, especially in this modern era. The technical specifications and applications of these robots could vary from warehouse to offshore uses. Technologies advancement of these robot have reached a peak where they are capable of doing everything on their own, such as monitoring their battery level and returning to their charging port if the battery is lower than certain values. But with every out of the ordinary technical specs comes a great cost. Thus, businesses that are still developing would not be able to install such advanced technologies. Therefore, in this project a similar kind of automated mobile robot that are able to retain the notion of independence, basic functionalities, and can be built at a lower cost will be discussed. The robot is designed to be a drawer and will navigate its own way by following a black line. To ensure it does so safely without any collisions, it will be equipped with Ultrasonic Sensors to sense any obstructions that are in its way. Lastly, the robot will confirm its location with the use of Radio Frequency Identification system.

Keywords: Autonomous Mobile Robot, Line following, Ultrasonic Sensor, Radio Frequency Identification System

1. Introduction

Plenty of processes need to be carried out steadily in a factory to ensure an efficient flow of production. Lacking human workforce and time-consuming, repetitive tasks affect a factory's productivity significantly. To bridge the gap, a solution that incorporates more usage of autonomous

**Corresponding author: hazli@uthm.edu.my*
2021 UTHM Publisher. All right reserved.

technology that could maintain an independent workflow to enhance efficiency, reduce time and costs whenever possible should be established and implemented. This project, for instance, could be the solution aforementioned as the drawers are built to be autonomously moving and would go to the destination where it is needed on its own. Not only that, the drawers could also store various sizes of objects as long as they can fit and withstand the weight. In the system, the drawer will portray its location, so the end-user would be able to locate and monitor the presence of the drawers. A line following robot is commonly a robot that travels on a predetermined path by following a line. This line could simply be a physical white or black coloured line or a more complicated path marking schemes, such as magnetic markers, laser-guided markers, or embedded lines [1]. The track is constructed so that the absorption coefficient of the line being followed varies greatly from the background track [2]. Various sensing techniques can be employed in order to detect these lines, and they are mainly decided based on the factor of accuracy and flexibility required [3]. Thus, making the type and positioning of the sensors a crucial role in building the robot [4]. Line following robots are used widely in industries, where they mostly function as material carriers or product deliverers from one point to another [5]. These types of robot are commonly applied in fully to semi-automated operations, from the industry point of view [6], for instance in public transports [7], restaurants [8], and factory [9] applications.

Fundamentally, a good autonomous mobile robot should be easy and free to control [10]. Thus, the robot should include a system that enables user access to the robot through wireless communication. In order to create a medium for users to communicate with the robot wirelessly, an interface that forms mutual contact, necessary cooperation and appropriate understanding between humans and the robot system is required [11]. In this project, the interface is provided through the Blynk Application and server. The Blynk Application practices an internet-based cloud which aids in remote accessibility [12] and controlling throughout the industrial setting. In correlation to the robot's location, a way to ensure that the robot reaches the correct destination is by implementing the Radio Frequency Identification technology in the system [13]. To add on to its complexity, a mechanism that enables the robot to stop at the sight of an obstacle by using ultrasonic sensors [14] and find another path to follow to overcome the obstacle should be implemented to achieve the optimal performance of the robot's functionalities.

2. Materials and Methods

This section provides a thorough overview of the methods and materials used in this project. The information will include all aspects related to the work procedures for each stage, namely, block diagram, software and hardware used, and the overview of the system flowchart.

2.1 Materials

The design of this project was made based on its functionality as a mobile drawer. Therefore, the physical of the robot will resemble a drawer. However, it is made autonomous where it could go to a specific place required on its own by following the lines on the floor. In order to get to its destination safely and smoothly, the robot will use multiple IR sensors in order to increase flexibility and accuracy. Furthermore, it will also have be able to detect any obstacles surrounding the robot. Additionally, this robot will be programmed to be capable of finding other ways to get back on track so that there will be no delays in deliveries. Moreover, the robot uses the RFID technology to verify its present location during movement. The list of components and software used for this project are listed below:

- Arduino Mega 2560 Microcontroller
- Cytron ESP8266 Wifi Shield
- LSS05 Auto-Calibrating line sensor
- Mifare RC522 RFID Kit
- NFC Tags
- HC-SR04 Ultrasonic Sensor
- 0.8Amp 5V-26V DC Motor Driver Shield
- Lithium-Ion Polymer Battery

- TT Motor & Wheels
- Robot Car Chassis
- Arduino IDE
- Blynk Application

Figure 1 below portrays the block diagram of this project. The system utilises the Arduino Mega 2560 Microcontroller as the main control system. The microcontroller is connected to the ESP8266 WiFi Shield to communicate with the Blynk server and application. The input and output for this project are represented through the Blynk Application. In the app, the virtual LCD act as a visual indicator of the robot's current location, and should it arrive at its desired destination, the robot will send a notification through the app to alert the users that the robot has arrived. Whereas, the input of this project relies on the virtual Buttons. The Buttons indicates where the robot should go. For instance, should Button 1 be pressed, the robot will head to location A. On the other hand, the Blynk server is responsible for all the smartphone and hardware communication. As for the motor controller, the prototype uses the L298P 0.8 Amp 5.00 V-26.00 V DC Motor Driver Shield and two dc motors. The motor controller provides the robot with mobility so it can travel. In addition, the speed of the motors is controlled by varying the Pulse Width Modulation (PWM) values.

Moreover, the robot uses a 12.00 V Lithium-Ion Polymer battery as a power supply. The Lithium-Ion Polymer battery is a rechargeable battery that is cheap, lightweight and has long battery life. The battery's rechargeable and lightweight characteristics sums up its convenience as no frequent buying, replacing, and disposing of batteries would occur. Furthermore, the battery would also not be too massive for the robot; hence, causing no interference to the robot's mobility. Additionally, the small amount of wasted energy is what caused the Lithium-Ion Polymer battery to be able to sustain a long battery life. As for the sensors, the prototype is equipped with three ultrasonic sensors and the LSS05 auto-calibrating line sensor. Lastly, for the RFID system, the Mifare RC522 RFID Reader is used to detect the NFC tags that marks the locations. The reason as to why NFC tags are used instead of the conventional passive RFID tags, aside from its capability of operating based on the same RFID protocol as well as 13.56 MHz frequency, is primarily because of its low cost and small size characteristics. Thus, making it easy for the tags to be hidden under the lines and can be kept out of sight.

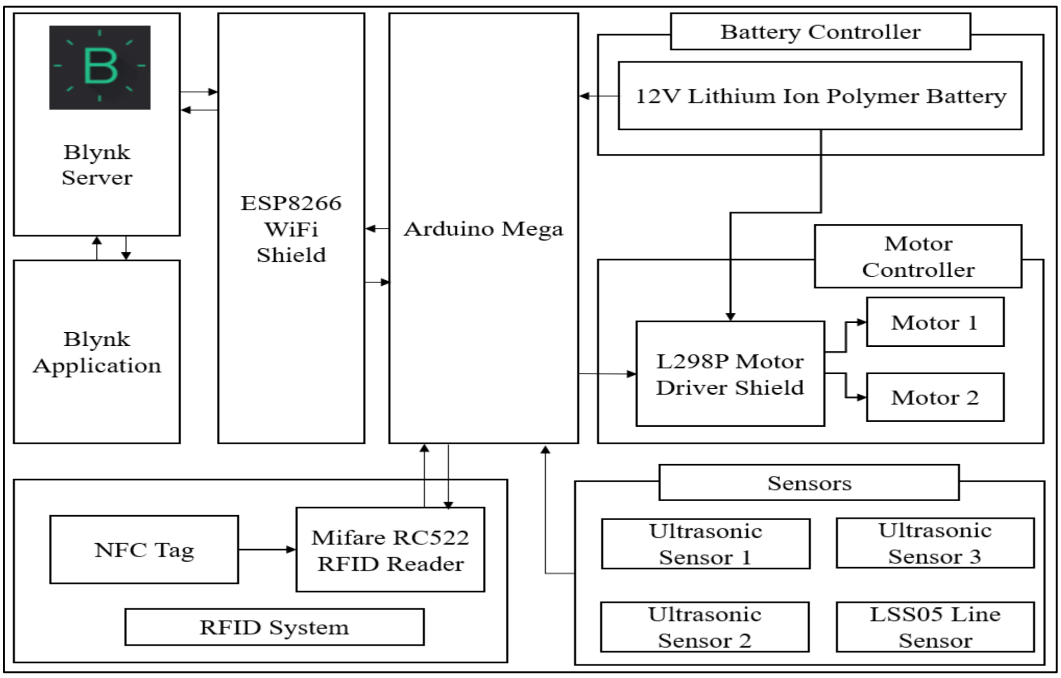

Figure 1: Block diagram of the system

2.2 Methods

Generally, the three main functions of this system are the RFID system, line-following, and avoiding obstacles. Figure 2 below represents an overview of how the system functions. The system starts by having the user check the battery level to determine if the power for the system is sufficient. Next, the user is required to determine their desired destination and pressing the button in the Blynk Application that correlates to their endpoint. Each button corresponds to one set location only. The LCD in the Blynk Application will then display the position the robot is heading towards according to the button pressed. For instance, if Button A is pressed, the LCD will display “Heading to Location A” and the same goes for each location. Once the user sets the target, the robot will then initiate Infra-Red sensors reading. If the LSS05 sensor detects the line, then the robot will move forward. Along with each movement, the Ultrasonic sensor will also be doing its part of the system. The Ultrasonic Sensors are used to ensure no collision occurs with any obstacles. The sensors will detect and calculate the distance between the robot and the obstruction. If all the sensor’s range is less than 20 cm, the robot will perform Avoiding Mechanism Movement 1, where it will stop for a second, go backward, turn right, and continue its way forward to get back on track and follow the line.

There is a total of three Avoiding Mechanism Movements that are catered for different situations when facing obstacles. Avoiding Mechanism Movement 2 is for when there is an obstruction to the front and right side of the robot. The robot will make a left turn, move forward and continue ahead to another line, whereas Avoiding Mechanism Movement 3 is the opposite of Avoiding Mechanism Movement 2 as there will be obstacles on the front and left side of the robot. Thus, the robot will make a right turn first, then continue forward onto another line. However, should there be no obstacles on the front side of the robot regardless of the right and left side, it will just remain its way forward. While moving along the line, the system will search for the destination tag, and if there is a read, it will record the IDs of tags within its range. The system will keep on recording and identifying until the robot has reached the location’s matching tag. If it achieved its target location, the robot would come to a halt for loading or unloading items to or from the drawer. The system will then read if there are more buttons pushed. Should there be another button pushed, the robot will continue its way to another destination, else the robot would return to its original place or also called “Home.”

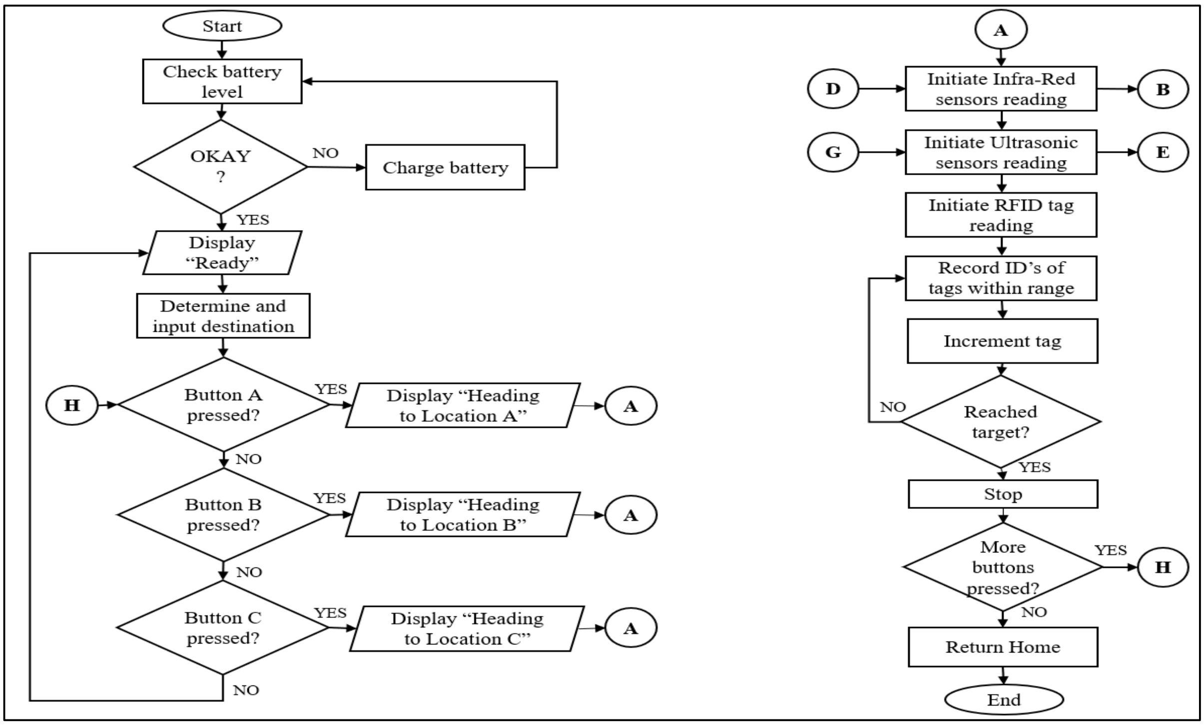

Figure 2: Flowchart of the system

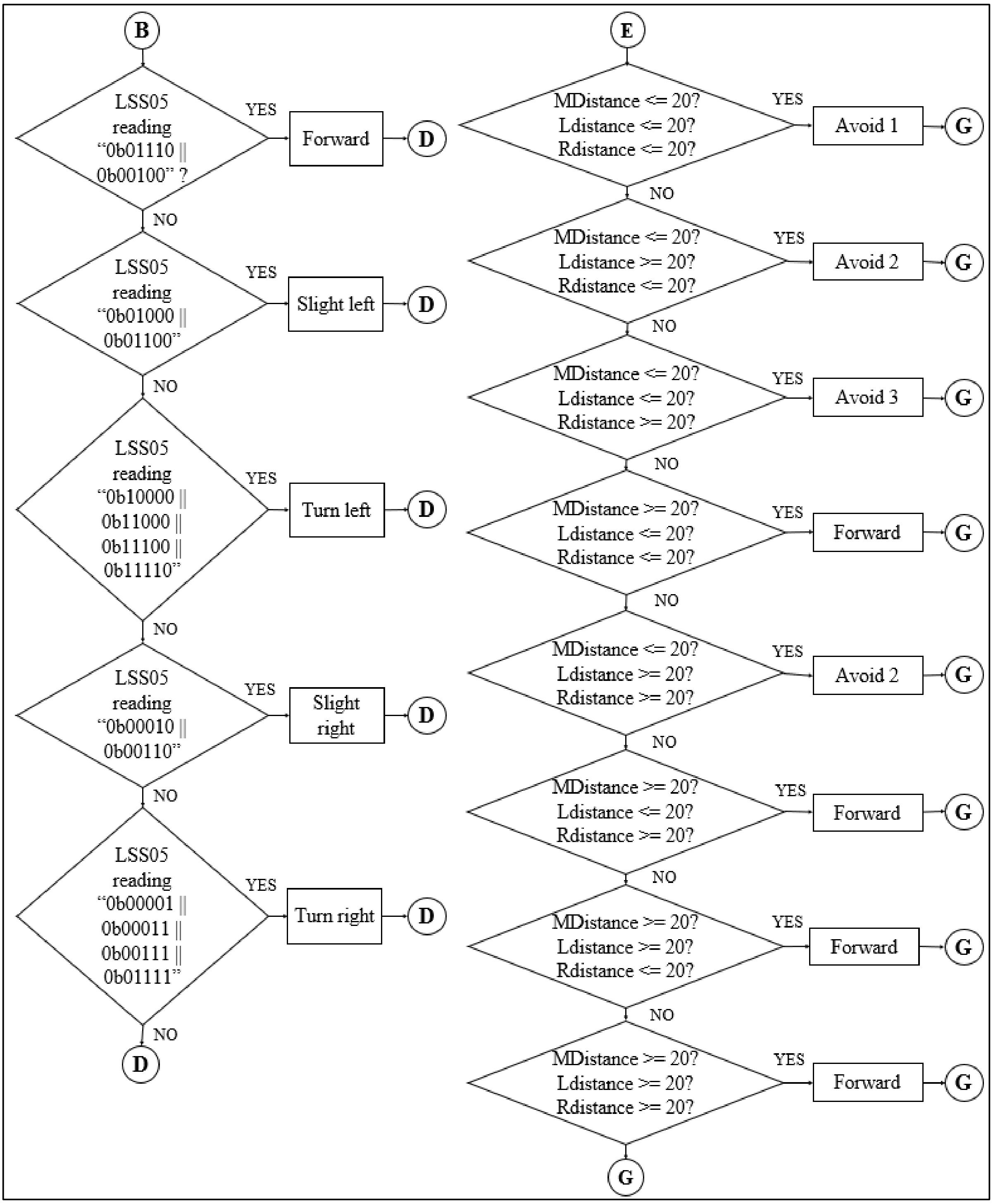

Figure 2: Flowchart of the system (continued)

3. Results and Discussion

This section focuses on the analysis and discussion of collected results and findings that was obtained from several experiments conducted with reference to the aims of the project. To recall, the purposes of the project are to create a system that enables controlling and mobilising drawers to move to a specific location autonomously with the aid of the line following mechanism. Next, is to use the Radio Frequency Identification system as a mean to communicate with the microcontroller and verify the arrival of the robot at a specified location. Lastly, to boost functionality in the system to allow the drawers to be able to avoid any obstacles along the path to their destination. The experiment performed targeted the workability, durability and accessibility of the prototype. The performance of the Autonomous Mobile Drawer (A-MOD) was examined and deliberated by comparing data attained from the experiments. The results are summarized into a number of tables, graphs and charts for easy viewing.

3.1 Project Layout

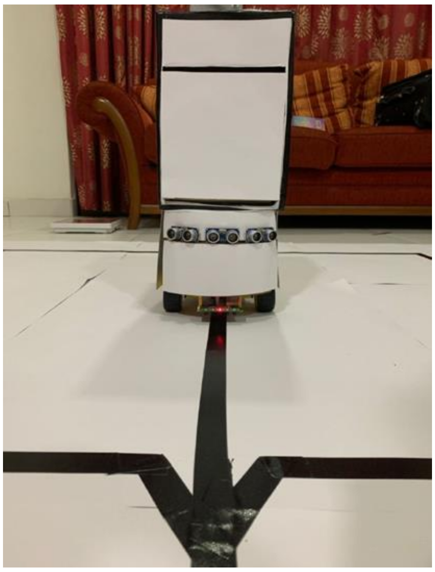

Figure 3: Front View of the Prototype

Figure 4: 3D View of the Prototype

Figure 5: Side View of the Prototype

Figure 6: Top View of the Prototype

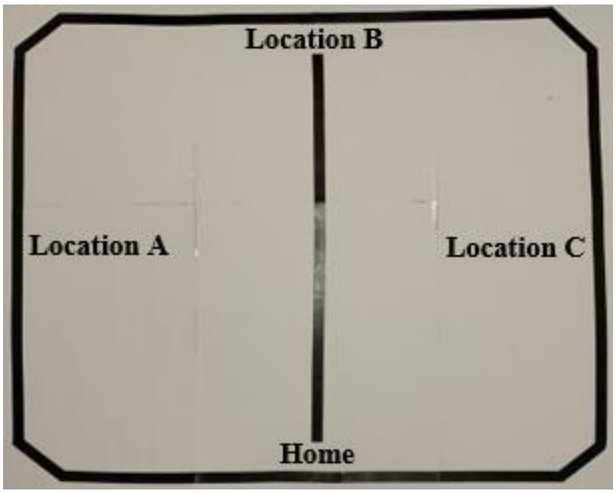

Figure 7: Line Map

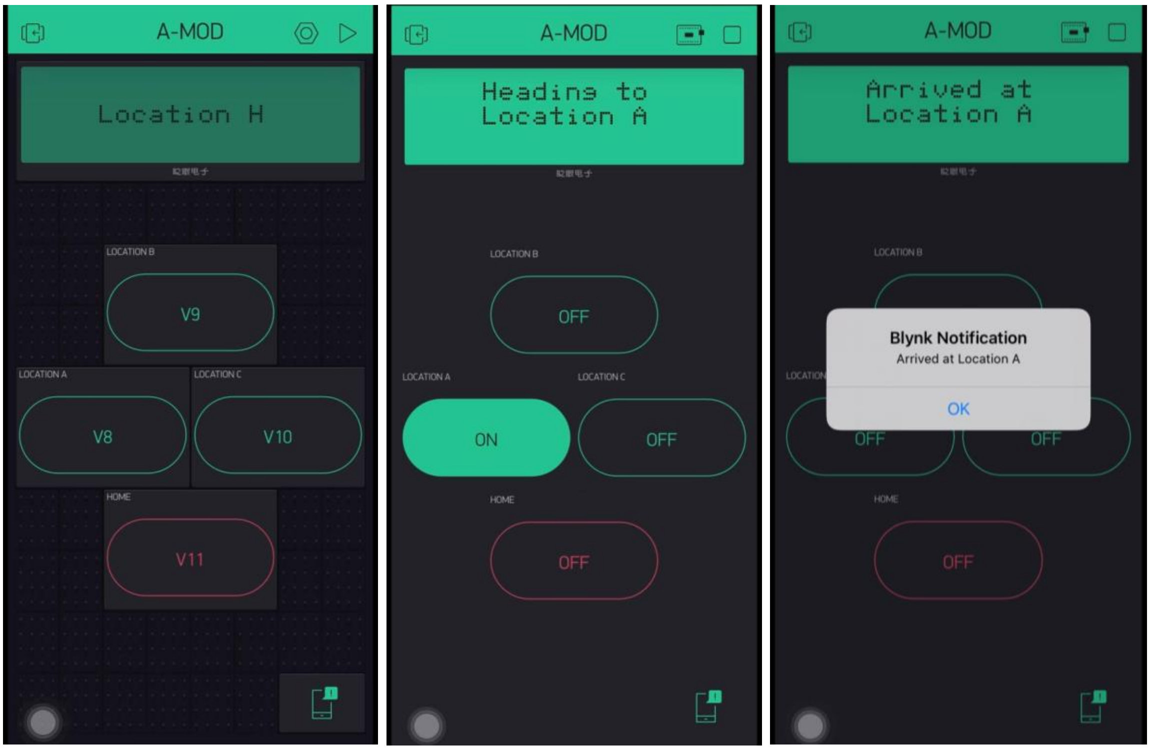

Figure 8: Blynk Application Interface Before, During, and After Arriving at a Location

Figures above portrays the layout of this entire project. Figure 3 above portrays the front view of the prototype whereas Figure 4 portrays the 3-dimensional view of the prototype. Meanwhile, Figure 5 represents the side view of the prototype and Figure 6 shows the top view of the prototype. The prototype is tested with the line map shown in Figure 7. Lastly, Figure 8 displays the Blynk Application interface before, during and after arriving at a location.

3.2 Results

The first experiment conducted was in search for the robot's ideal speed. In order to find the speed where the robot moves at optimal condition, the robot was programmed and tested with 6 different speed settings ranging from 50 PWM to 100 PWM. The test was repeated three times for each speed value. The number of times the robot strayed from its path, as well as the number of times it stopped on its way from the starting point to the end point was observed to determine the accuracy and success rate of the robot's movement for each speed value. Table 1 displays the results obtained from this experiment.

Table 1: Results of Speed Test

No. of Experiment	Motor PWM	Result	Explanation
1		Failed	Off Track
2	100	Failed	Off Track
3		Failed	Off Track
1		Failed	Off Track
2	90	Failed	Off Track
3		Failed	Off Track
1		Succeed	Reach Destination
2	80	Failed	Off Track
3		Failed	Off Track
1		Succeed	Reach Destination
2	70	Succeed	Reach Destination
3		Failed	Off Track
1		Succeed	Reach Destination
2	60	Succeed	Reach Destination
3		Succeed	Reach Destination
1		Succeed	Reach Destination
2	50	Failed	Frequent Stops
3		Failed	Frequent Stops

The result is significant at the 60 PWM Motor Speed, where all three of the experiments was successful compared to the rest. Thus, making 60 PWM Motor Speed the ideal speed for the robot. A possible explanation for this might be related to the compulsory BlynkTimer function that allows data to be sent periodically. The function is required so that data can be sent in intervals to avoid interference with Blynk library routines, as well as keep the "void loop ()" as clean as possible in the sketch [15]. The timer interval is programmed to send data every 0.1 second, therefore, when the robot moves too fast, such as at 90 and 100 PWM, it wasn't able to grasp the sensor's data as quick. Improvements in the success rate can be seen as the PWM value goes down to 80, 70 and 60. However, at 50 PWM, the success rate drops as the robot frequently stops which may correlate to the motor driver's capacity.

In the second experiment, the workability of the prototype's two essential functionalities, which are line following, and RFID system, was tested. An approximately 4-meter line map, with four different checkpoints, to symbolize the locations the robot should head towards, was customized as the track for the prototype to follow as shown in Figure 7. The experiment begins by having the robot moves from its starting point, which is called "Home" and represented by "H". Then, the robot heads to location A, B, and C accordingly, followed by a trip back "Home". Later on, the experiment continues with random location selection between the four points, as per recorded in Table 2 below. The initiative taken to experiment with different locations was to ensure that, although the robot would have to go in loops, it will not take too long for it to complete each route. To determine the success rate of the prototype's line following mechanism, the number of times the robot strayed from its path, as well as the time taken to complete its route, was measured. Meanwhile, the RFID system was tested by seeing if it successfully recorded the tags along the way.

Table 2: Result of the Line Following Mechanism and RFID System Efficiency Test

No. of Experiment	Route	Time Taken to Complete Route (min:s)	No. of Strays	Record of Location
1	H – A – B – C – H	0.50	0	Successful
2	H – A – C – B – H	1.28	0	Successful
3	H – B – A – C – H	1.46	0	Successful
4	H – B – C – A – H	2.05	1	Successful
5	H – C – A – B – H	1.27	0	Successful
6	H – C – B – A – H	2.15	1	Successful
7	H – A – B – C – H	0.51	0	Successful
8	H – A – C – B – H	1.27	0	Successful
9	H – B – A – C – H	1.47	0	Successful
10	H – B – C – A – H	1.23	0	Successful

Table 3: RFID System Corresponding Tag at Location

Location	Tag ID	Recognition
A	2B 81 1F AD	Successful
B	FB 17 33 AD	Successful
C	0B CB 3A AD	Successful
H	0B 5C 40 AD	Successful

In this experiment, we observed the line following's efficiency by setting a time goal, which is below 2 minutes, for the robot to complete its route. From the results obtained, the average time taken for the robot to complete its journey is approximately 1 minute and 32 seconds, where the result ranges between 50 seconds to 2 minutes and 15 seconds. The average time taken for A-MOD to complete its task indicates an acceptable value as it travels at a speed of 60 PWM along an approximately 4-meter line, from its original location, to three other checkpoints and back to where it started. In some routes, the robot even has to go through two cycles to complete them. However, there were twice where the robot was not able to complete its task on time, thus, we can assume that the success rate for its line following mechanism is at 80.00 % as both times correlates with the number of strays that occurred during movement. Interestingly, albeit the robot got off track, it was still able to turn around and get back on line to continue its route, further proving that the line following mechanism is effective. On the other hand, the average number of times the robot strayed from its path accumulates to an average of 0.2, indicating that A-MOD's LSS05 line sensors have a relatively high accuracy. As for the RFID system's efficiency, the recognition of tags at their specific location, as shown in Table 3, was tested first to determine the effectiveness of the RFID reader. Then, the RFID system was tested along with the line following mechanism test, and in each experiment the robot was able to locate and verify its presence upon reaching the destination, as per Figure 8. The robot was able to complete the route set, hence, signifying that the RFID system has a 100.00 % success rate.

Next, the different ways A-MOD will react when encountering obstacles in different situations was tested. Initially, the Avoiding Mechanism Patterns was different, where in each pattern the robot would be able to get back on its original line. Although the patterns work in avoiding small obstacles and getting the robot back on the same path, the approach has a great disadvantage when tested with a large size obstacle. Because of the reactions being programmed according to specific number of seconds in each turn, when tested with a larger sized object, the robot goes back to the obstacle after its attempt to avoid it. Consequently, the method becomes ineffective. With that, new movements were designed as per Table 4. Four different situations were created to test the effectiveness of the new movements. Based on Table 5, there were twice in Situation B and once in Situation C where the robot did not react as planned. A possible reason to this phenomenon could be the placement of the ultrasonic sensors. However, the robot was still successful in dodging the obstacles in all of the attempts. In situation A, we can observe that when the robot reaches the maximum set distance of 20 cm from the obstacle placed in front of it, it will constantly move in a form categorised as Movement 2. In Movement 2, the robot will make a left turn, then move forward to search for another line. The result is the same for Situation B, where the obstacle is placed at the same maximum distance of 20 cm, in front and on the right of the robot. Whereas for Situation C, the obstacle is moved to the left side of the robot. Thus, it will react according to Movement 3, which is where the robot will make a right turn, then move forward and continue to the nearest line. Last, as for Situation D, the obstacle was placed at the front, left and right side of the robot, it will follow Movement 1. The robot will stop for a second, go backward, make a right turn, continue forward to another line. Figure 9 depicts the graph of mode of movement for each situation.

Table 4: Result of the Line Following Mechanism and RFID System Efficiency Test

Movement	Description
1	Robot stops for a second, go backward, make a right turn, continue forward to another line
2	Robot will make a left turn, then move forward to another line
3	Robot will make a right turn, then move forward to another line

Table 5: Result of the Line Following Mechanism and RFID System Efficiency Test

No. of Experiment	Situation A	Situation B	Situation C	Situation D
	Movement			
1	2	2	3	1
2	2	2	3	1
3	2	2	3	1
4	2	1	3	1
5	2	2	3	1
6	2	2	3	1
7	2	2	1	1
8	2	2	3	1
9	2	1	3	1
10	2	2	3	1

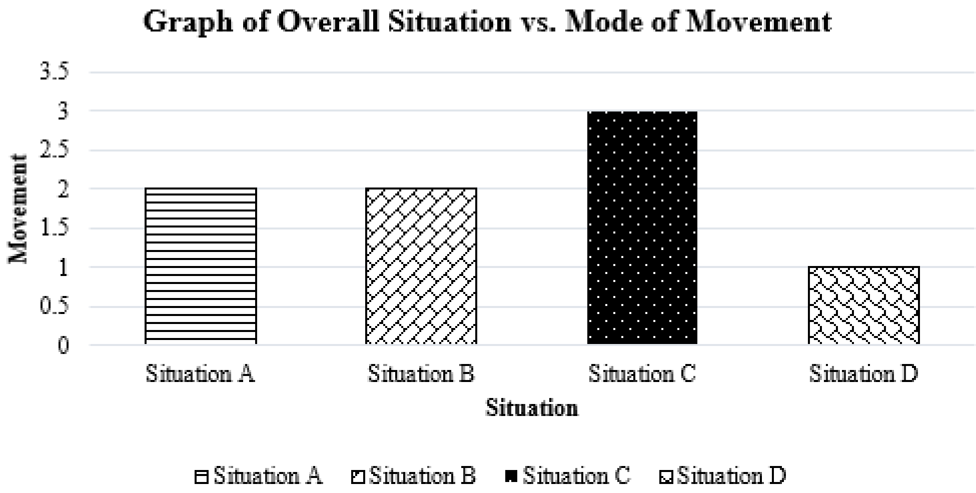

Figure 9: Graph of Overall Situation vs. Mode of Movement

The final test conducted was to test the durability of the Autonomous Mobile Drawer. The experiment was regulated by measuring the voltage level of the battery during usage at every five minutes interval. The aim for the test is to observe the energy density and self-discharge properties of the battery, as well as determine the amount of time the robot can operate at maximum performance. It can be seen that the voltage level of the battery decreases gradually around 4.00 – 6.00 V after each five minutes interval. The findings of the experiment in Figure 10, proved that a clear benefit of using the Lithium-ion Polymer Battery is that it is capable of powering the Autonomous Mobile Drawer for approximately 2 hours and 8 minutes, with the initial standard state of charge is 12.44 V at 100.00 %. The 2 hours and 8 minutes time of operation is perceived as an ideal time of operation before having the robot to recharge its power as the robot consists of numerous components.

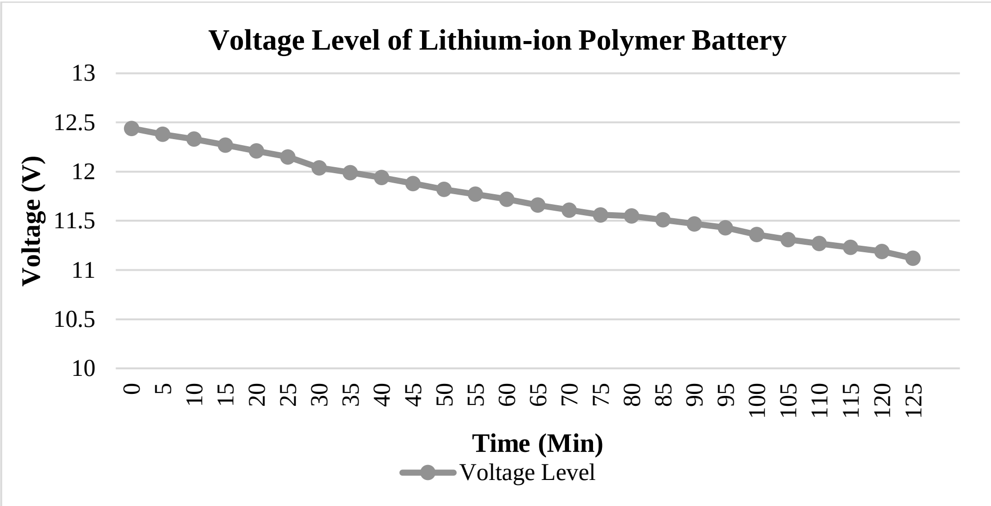

Figure 10: Voltage Level of Lithium-ion Polymer Battery

Essentially, the aim of the experiments was to determine the rate of success for the Autonomous Mobile Drawer's basic behaviours, which is following a black line towards its destination, avoiding any obstruction in its way, as well as, verifying its location by using RFID technology. As can be seen from the results of the Efficiency Test of the Line Following and RFID system, the success rate for both functionalities is relatively high as the Autonomous Mobile Robot mainly finishes its designated cycle in time, except for the few times it didn't. The few times where the robot was not capable of reaching its goal is correlated with being strayed from the line, however, it was still able to complete its cycle albeit the extra time taken, further proving the rate of success for the RFID system.

Besides that, the results of the experiment in testing the efficiency of the obstacle avoiding mechanism showed a high percentage of success. The Autonomous Mobile Drawer showed quite a constant reaction in following a pattern to avoid the obstructions according to the situation. There are exactly four different situations where the robot was put to a test against. The first and second situation, Situation A and B, was designed to test if the robot will make a left turn, then move forward to another line. Contrarily, as for the third situation, Situation C, the robot was tested on whether it will make a right turn, then move forward and continue to another line. Lastly, the situation changed to Situation D, where the obstacles are placed to the right, left and front of the robot. This situation was created to see if the robot will stop for a second, go backward, make a right turn, then continue forward to search for another line.

The final experiment conducted was concerning its durability. Altogether, it was proven that the Lithium-ion Polymer Battery was the ideal battery to be used for the Autonomous Mobile Robot as the results showed a linear and constant decrease in voltage level, thus no sudden power shortage. The experiment also confirmed that the robot will be able to function for approximately 2 hours and 8 minutes before having to recharge its battery.

4. Conclusion

Based on the finding of the experiments, it is apparent that the Autonomous Mobile Drawer is capable of optimising its functionality in the industry. This is because, although most of the industrial line followers are able to follow their lines and avoid obstacles, they are not able to go out of their path to completely avoid the obstacles and resume their tasks, unlike the Autonomous Mobile Drawer. The industrial line followers that are commonly used nowadays will stop at the sight of an obstacle, however, it will not move unless the obstacle has been cleared. This situation may result in a great loss of time, and consequently delay any industrial work processes that require the robot's assistance, such as when the robot is used to transport any crucial items or materials needed for manufacturing processes. With that, the decision to install the avoiding mechanisms were made to ensure a smooth journey for the robots. The Autonomous Mobile Drawer can also be controlled by using the Blynk Application. which makes it easy for anyone to access and call the robot should they require any assistance from the robot.

All the objectives that were initially set for this project was successfully achieved. The robot is able to use the LSS05 sensors to move on its own while being guided with a line as proven in Table 2. Thus, the objective of developing a system that enables controlling and mobilising drawers to move to a designated position autonomously with the aid of the line following mechanism is achieved. The robot is also capable of notifying the users of its destination as shown in Figure 8, therefore validating the objective of utilising the Radio Frequency Identification navigation system as a medium to communicate with the microcontroller and verify the arrival of the robot at a specified location. The robot proved that it is able to follow the movements set in order to avoid any obstacle as per Table 5, hence, achieving the objective of enhancing functionality in the system to allow the drawers to be able to avoid any obstacles along the path to their destination.

Although all three objectives of this project were achieved, there are a number of limitations and several areas that can be improved on to ensure the robot can further deliver optimal performance in the industries. For instance, utilising a more advanced line following sensor such as the LSA08 to increase line detection accuracy and ultimately reduce the number of times the robot may stray from its path. Other than that, installing a Proportional and Differential (PD) controller to it, could also make the robot faster and less wobbly. The PD controller works in a way where the controller uses its own feedback loop, which can consist of any sort of sensor, but in this case, it will be the IR sensors, to continuously measure the error value. From the error value, it will calculate and adjust accordingly to perform more efficiently and make less error. The customization of the line map could also be improved on, particularly in adding more lines nearby each other. Adding more lines would ensure the robot to always be able to find an alternative route should it stray or need to avoid any obstacle from its original path. Moreover, an excellent addition to the system would be Shortest Path Finding algorithm & being able to navigate junctions, so the robot can reduce the time taken to complete its route. Additionally, using motor with higher torque value is also crucial to guarantee the robot can withstand the load it is carrying. Lastly, selecting an alternative RFID reader. Thanks to its low power consumption, low cost, and compact read and write chip size characteristics, the non-contact 13.6MHz Mifare RC522 RFID reader is an excellent option. The card reading distance is, however, restricted to 6 centimetres, making it mandatory to position the RFID reader at the bottom of the robot. It is a little inconvenient to position the RFID at the bottom of the robot, as proper traction is important. However, should anything be stuck under the robot it would definitely mess up with the RFID component. Which is why choosing another RFID reader with larger reading distance could help immensely in ensuring optimal performance of the robot.

Acknowledgement

This research was made possible by funding from the Universiti Tun Hussein Onn Malaysia. The authors would also like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] J. Thirumurugan, and M. Vinoth. "Line following robot for library inventory management system," in International Conference on Emerging Trends in Robotics and Communication Technologies (INTERACT), Coimbatore, India 3-5 Dec. 2010. IEEE Explore, 2010.

[2] A. Roy and M. Noel (2015). "Design of a high-speed line following robot that smoothly follows tight curves". International Journal of Computers & Electrical Engineering, vol. 56, p. 732–747, Nov 2016. Available: Sciencedirect https://www.sciencedirect.com/science/article/ pii/S0045790615002190? via %3Dihub#fig0045. [October 31, 2020].

[3] S. K. Das. "Design and Methodology of Line Follower Automated Guided Vehicle-A Review". IJSTE - International Journal of Science Technology & Engineering. vol. 2, no. 10, April 2016. [Online]. Available: ResearchGate https://www.researchgate.net/ publication/301255605 _Design_and_Methodology_of_Line_Follower_Automated_Guided_Vehicle-A_Review. [Accessed October 31, 2020].

[4] G. Patil and S. Pawar. "Automatic Speed Control System for Line Following Robot." International Research Journal of Engineering and Technology (IRJET), vol. 3, no. 12, p. 177-179, Dec 2016. [Online]. Available: IRJET https://www.irjet.net/archives/V3/i12/IRJET-V3I1233.pdf. [October 31, 2020].

[5] K. Prince and K. Raghav. "Smart Waiter using Line Following, RFID and Object Detection". International Journal of Recent Technology and Engineering (IJRTE). [Online]. Available: https://www.ijrte.org/wp-content/uploads/papers/v8i3/C6645098319.pdf. [October 31, 2020].

[6] M. Mehdi Samaatiyan and Mehran Pakdaman, "Design and implementation of line follower robot", Second International Conference on Computers and Electrical Engineering, 2009.

[7] O. Gumus, and M. Topaloglu "The use of Computer Controlled Line Follower Robots in Public Transport," in Procedia Computer Science, 12th International Conference on Application of Fuzzy Systems and Soft Computing, ICAFS 2016, 29-30 August 2016, Vienna, Austria, 2016. Elsevier, 2016. pp. 202 – 208.

[8] A. M. Rokonuzzaman, S. R. M.D and M. H. Mim, "Automated Restaurant Food Service Management system using a Line Follower Robot," in International Conference on Mechanical, Industrial and Energy Engineering, Bangladesh, 2014

[9] S. Tayal, and H. P. G. Rao. "Line Follower Robot: Design and Hardware Application," 2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 2020, pp. 10-13, IEEE Explore, 2020.

[10] S. Reddy and B. Vangipuram. "Line Tracking Pick and Place Robot using RFID Technology". International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,MVSR Engineering college, Hyderabad, India, vol. 4, no.

10, p. 8059 – 8063, 10 Oct 2015. [Online]. Available: IJAREEIE https://www.ijareeie.com/upload/2015/october/32_LINE.pdf. [October 31, 2020].

[11] S. A. Ohya, and S. Yuta. “A network-based stationaries rental service performed by an autonomous mobile robot”. Conference: Robot and Human Interactive Communication Proceedings. 11th IEEE International Worksho. Feb 2002, IEEE Explore, 2002.

[12] M. S. Mohd Hafizi, N. A. Mat Leh. "Developing a Monitoring System for Tripping Fault Detection via IoT," 2018 9th IEEE Control and System Graduate Research Colloquium (ICSGRC), Shah Alam, Malaysia, 2018, pp. 110-115, IEEE Explore, 2018.

[13] A. Abdulkareem, and V. Ogunlesi, “Development of A Smart Autonomous Mobile Robot for Cafeteria Management”. International Journal of Mechanical Engineering and Technology (IJMET), vol 10, p. 1672-1685, 2019. Available: ResearchGate, https://www.researchgate.net/publication/331035208_Development_of_a_Smart_Autonomous_Mobile_Robot_for_Cafeteria_Management. [Accessed October 31, 2020].

[14] S. Adarsh. “Performance comparison of Infra-Red and Ultrasonic sensors for obstacles of different materials in vehicle robot navigation applications.” IOP Conference Series: Materials Science and Engineering. IOP Publishing, 2016 [Online]. Available: IOPscience, https://iopscience.iop.org/article/10.1088/1757-899X/149/1/012141/pdf.

[15] P. Seneviratne. Hands-On Internet of Things with Blynk. Packt Publishing Ltd. [E-book] Available: Google E-Books.