DESIGN AND SIMULATION OF A MOBILE ROBOT PLATFORM FOR NAVIGATION AND OBSTACLE DETECTION

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Abstract:

Mobile platforms are expected to gain access to risk zones and hazardous environment. A typical example is the infectious disease environment to deliver items to a sick patient. The robot is aimed to manoeuver round flat grounds in indoor environment. Computer aided design (CAD) models of the selected concepts were developed in Fusion360 and imported into SolidWorks to optimize and improve the design. The design is focused on the development of the wheelbase. Arduino Microcontroller was the system and codes control board and it was developed using the Arduino software. The motor driver was used to drive the DC motor for robot navigation with ultrasonic sensor for obstacle detection at a range of 20 cm. Result shows that the robot was able to navigate round flat ground while detecting obstacles within 20 cm.

1 Introduction

1.1 Mobile Robots

Mobile platforms are expected to gain access to risk zones and hazardous environment. A typical example is the infectious disease environment to deliver items to a sick patient. Entering such areas may endanger the health human. These robots may be remotely controlled to carry out specific tasks to support clinicians [1]. Mobile robots can execute several tasks for humans in their day to day activities [2,3]. Wheeled mobile robots operating safely and accurately in real life environments usually have vast applications that ranges from simple delivery tasks to assembly operations [4], therefore improving their control has been greatly researched. Over the years' mobile platforms have played a significant role in robot technology.

They have been used increasingly as assistive robots, service robots, robots in manufacturing industry, household robots for transporting items in domestic environments, and in environments that are hazardous for humans [5-7]. Research activities in robot navigation can be promoted with the aid of mobile robot platforms and obstacle avoidance capability. [8] introduced a concept and design of a mobile robot platform. A wheeled mobile robot to replace the concept of air cushion units on a frictionless air cushion table thus enabling long-term and high precision simulations using orbit dynamics was proposed by [9]. A mobile robot that was used in a modern poultry house was developed to assist farmers to collect floor eggs daily. Poultry Bot was tested and successful in moving through the environment [10]. [11,12] integrated Ultrasonic and Infrared sensors in different mobile robot platform for acquiring distance data.

The growth of wireless technologies is fast and has made a visible impact in our everyday life. The impact is mostly in the area of entertainment, information transfer, and communication [13]. The proposed mobile robot with obstacle detection capability can be used to help people in executing specific tasks both in healthcare and beyond, especially when the tasks are dangerous for humans. For example in search and rescue operations, evacuations, and infectious disease scenarios.

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2 Methodology

2.1 Wheelbase

The robots' mobile platform is a wheelbase with four drive wheels, two at the front and two at the rear which provides stability for the body and also a means of navigation. This type of platform is easy to control and is it adaptable to indoor environment where there are no stairs or big bumps. The requirements specify that the robot should have four wheels, and be able to drive on flat surfaces, which informed the wheelbase design.

The drivetrain consists of DC motors and rubber wheels. In the differential drive system holonomic and non-holonomic drive were investigated. Holonomic drive allows motion in any direction without any kinematic constraint and rotate independently but in non-holonomic drive, the robot can move forward and backward like e.g. a car that cannot rotate around its axis without changing its position. Non-holonomic drive was considered because it greatly simplified the design, as the upper part of the robot is dexterous enough to move sideways. The drive uses four DC motors that is attached to four standard wheels which is able to move steadily in indoor environment.

2.2 Direct current motor

DC motors are widely used in mobile robots to translate electrical pulse into mechanical movement. In this configuration, we have positive and negative terminals. Connecting the positive and negative terminals to a DC power source will move the motor to one direction and reversing the polarity moves the motor to reverse direction. Rotation per minute (rpm) is used to indicate the speed of a DC motor. The motor speed increases with increasing voltage. The motor speed depends on current, load and voltage. The motor current consumption is increased as the load increases given a fixed voltage.

In the development of the mobile robot, a strong magnetic double axis four geared DC motors were installed to drive the wheels and to navigate the mobile robot to the goal. DC Geared motor consist of a reduction gear train which significantly decreases the speed of the motor rotation thus increases the torque. The key characteristics of DC motors are high speed, low torque, and its reversibility. Table 1 shows the specification of the DC motor.

2.3 Design and assembly

Structural integrity, modularity, weight, and a platform to provide stability were all factors that affected the design decision. The concept includes four DC motors attached to four wheeled non-holonomic drive. Parametric CAD models of the selected concept were produced in fusion 360. With the design specifications in mind, drafts, sketches and CAD models were designed with desired dimensions shown in Figure 1.

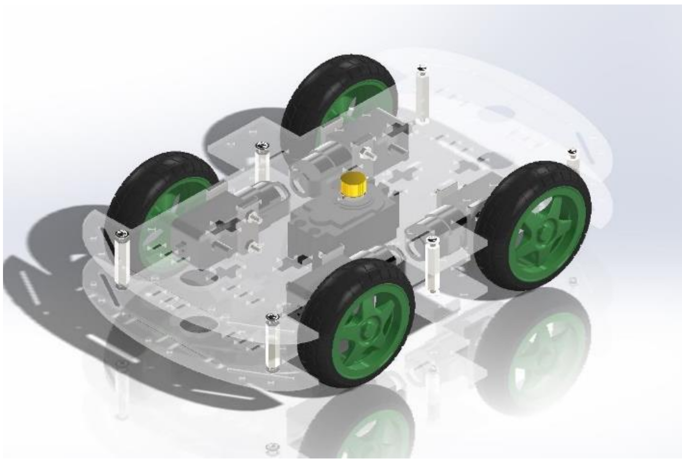

Figure 1. Wheelbase Design.

2.4 Ultrasonic sensor

Ultrasonic sensing is a good way to sense proximity with high level of reliability and it is commonly used with microcontrollers platform like Arduino. The sensor works by measuring the distance to an object using ultrasonic sound waves with the use of transducers to send and receive ultrasonic pulses that relay back information about the proximity of an object. Ultrasonic sensor is reliable in any lighting environment for both indoor and outdoor environments.

2.5 Motor driver L298

The motor driver in Figure 2 acts as a current amplifier whose function is to take a low current control signal and turn it into a higher current signal in order to drive a motor. Motor drivers are used to control motors in autonomous robots since the Arduino cannot supply enough current to control or drive the motors. They act as an interface between Arduino and the motors with ICs designed to control a pair of DC motor simultaneously. It works on the concept of H-bridge. As shown in Figure 3. H-bridge is a circuit that allows the voltage in either direction to control the motor direction.

The voltage changes its direction to be able to rotate the motor in anticlockwise or clockwise direction based on the inputs provided across the input pins as logic 1 and logic 0 which makes H-bridge IC ideal for driving a DC motor. There are a total of 4 input pins, 4 output pins with 2 enable pins. However, 2 input pins, 2 output pins and 1 enable pin are for each motor. Motors direction depends on the logic inputs applied at these pins.

Figure 2. Motor driver L298.

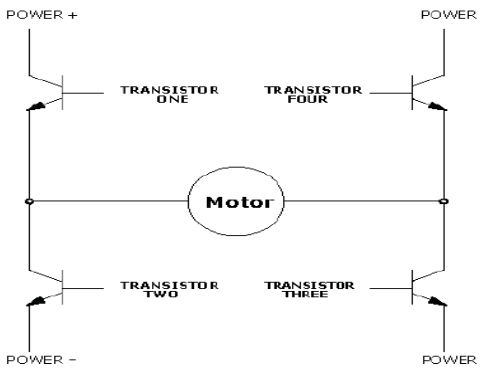

Figure 3. H-bridge circuitry.

Figure 3 there are two terminals +Ve and –Ve. To move the robot in the forward direction, the current goes from +Ve to –Ve and the motor will rotate in one direction, clockwise (CW) or forward direction. However, if the terminal is changed and the current flows in the reverse direction, the motor will rotate in the counter clockwise (CCW) direction. There are five ways header pin for external control connection to the microcontroller. The pins consist of ground (GND), Purse Width Modulation (PWM), CCW, CW, and Vcc to activate the motors, controlling the speed, and changing directions of the motor.

2.6 DC Motor code

Figure 4 and 5 respectively shows the transmitter and receiver flow diagram of the DC Motor control, communicating via the wireless module to navigate the robot. To prevent a crash, an ultrasonic sensor is used to stop the motor if the robot is 20 cm away from an object. To increase the performance of the motors, data is only written to them when it is different from the previous. An addition of a comparator within the code allowed for the current values to be compared to the previous value that had been stored.

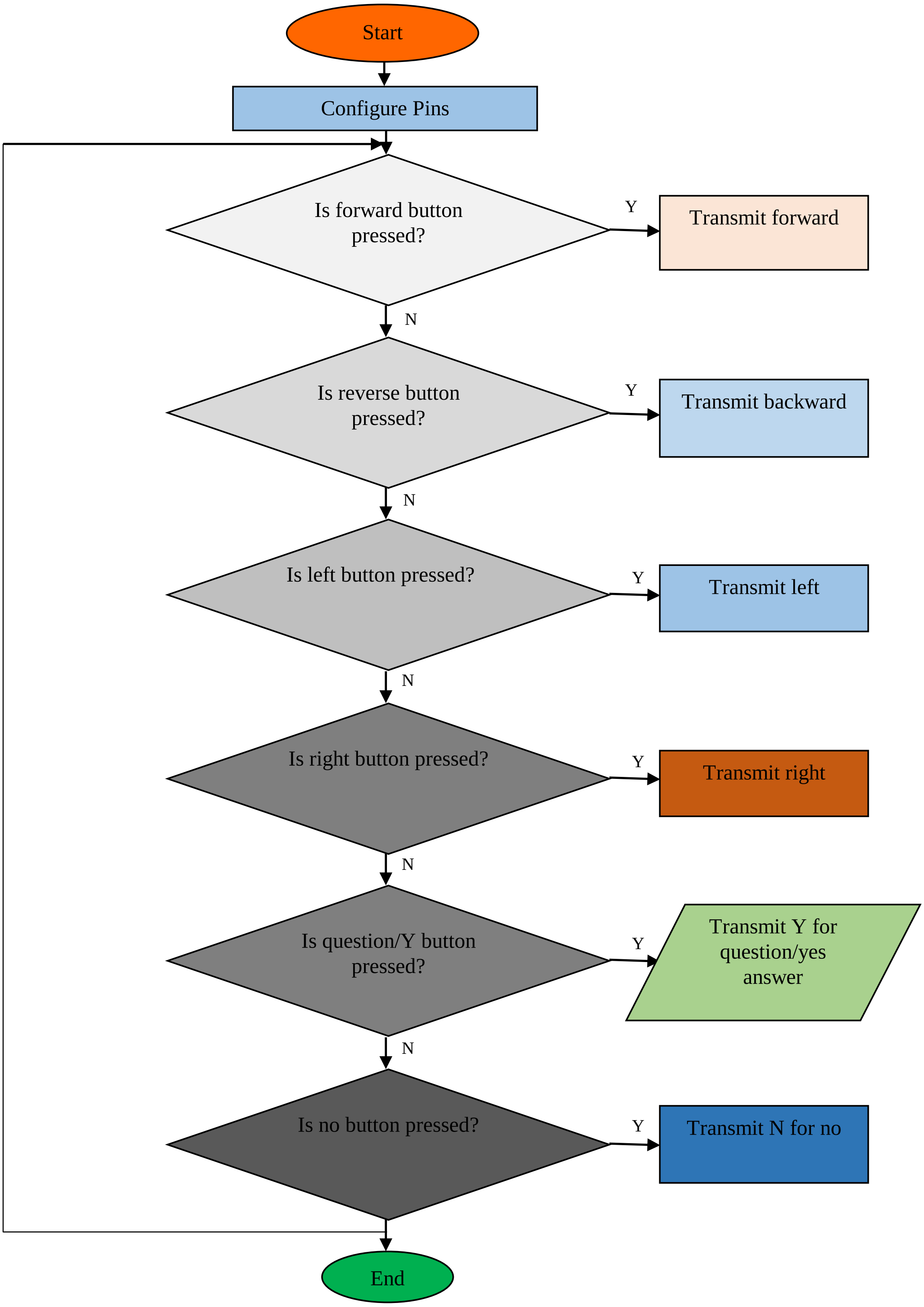

Figure 4. Transmitter control flow diagram for the DC motor.

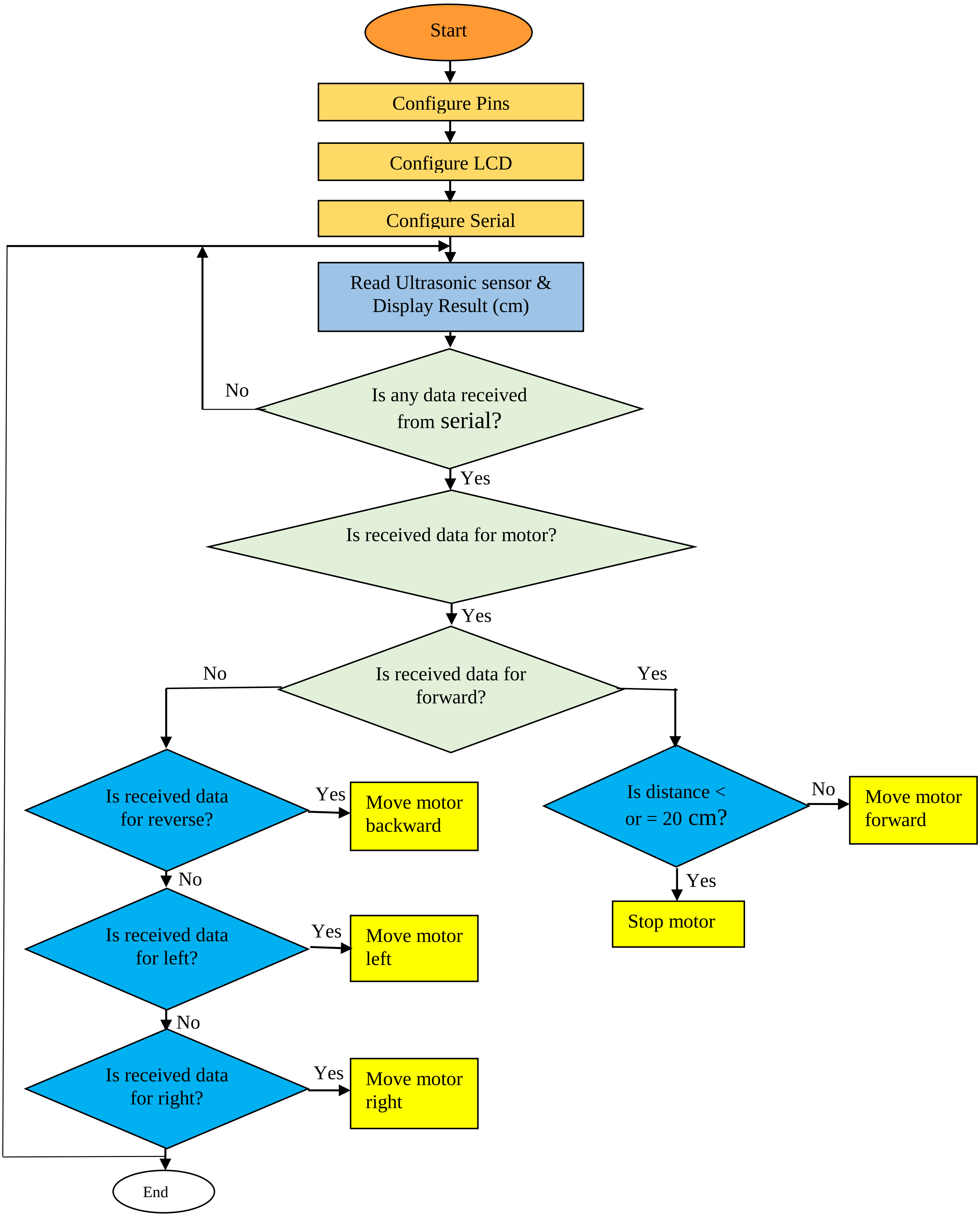

Figure 5. Receiver Control Flow Diagram for the DC Motor.

3 Results and discussion

3.1 Robot Navigation Simulation Result

The motor driver input pins N1, N2, N3 and N4 are connected to A0, A1, A2, A3 and A4 respectively to control the motor direction The DC motor is connected to output terminals of L298. EN1 pin is connected to the 5V DC to drive the motor.

Algorithm 1:

```
void stop(){
digitalWrite(A0, LOW); //=IN1
digitalWrite(A1, LOW); //=IN2
digitalWrite(A2, LOW); //=IN3
digitalWrite(A3, LOW); //=IN4
```

Result: Stop motor1 and motor2

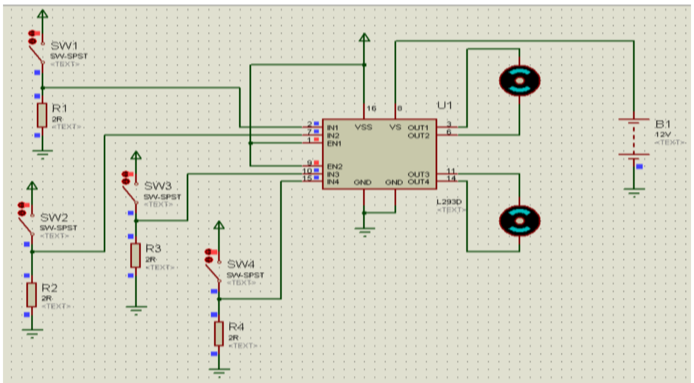

Figure. 6 Circuit Simulation to Stop Motor.

Algorithm 2:

```
else{ if(chr == FORWARD)
{ digitalWrite(A0, HIGH); //=IN1
digitalWrite(A1, LOW); //=IN2
digitalWrite(A2, HIGH); //=IN3
digitalWrite(A3, LOW); //=IN4
delay(50); stop();}}
```

Result: Move motor1 and motor2 forward

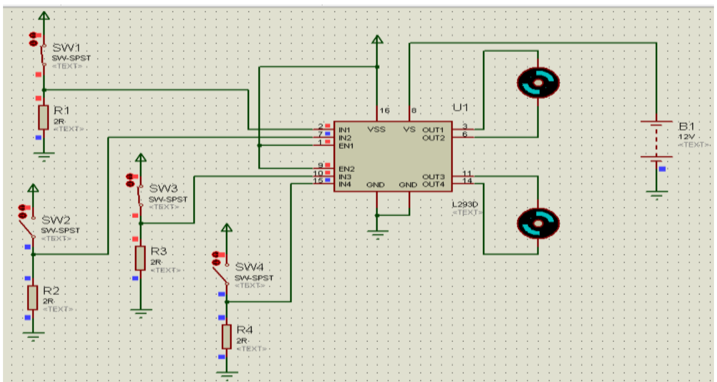

Figure 7. Circuit Simulation for Forward Navigation.

Algorithm 3:
if(chr == BACKW Result: Move motor1 and motor2 forward
ARD)
{digitalWrite(A0, LOW); =IN1
digitalWrite(A1, HIGH); =IN2
digitalWrite(A2, LOW); =IN3
digitalWrite(A3, HIGH); =IN4
delay(50); stop();}

Result: Move motor1 and motor2 anticlockwise (reverse)

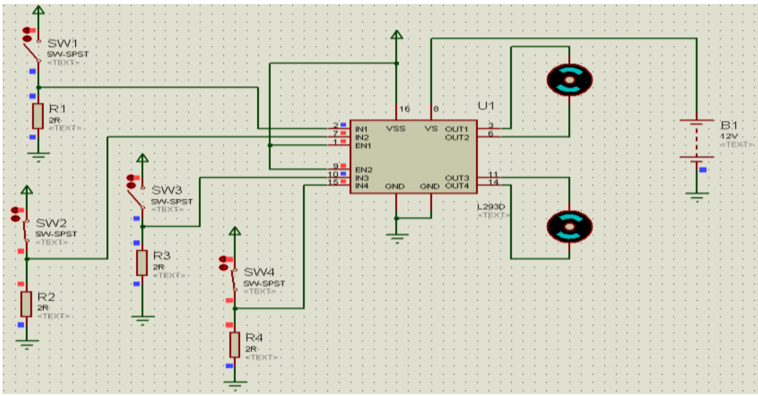

Figure 8. Circuit Simulation for Reverse Navigation.

Algorithm 4:
if(chr == LEFT)
{ digitalWrite(A0, LOW); =IN1
digitalWrite(A1, LOW); =IN2
digitalWrite(A2, HIGH); =IN3
digitalWrite(A3, LOW); =IN4
delay(50); stop(); }

Result: Moved motor left

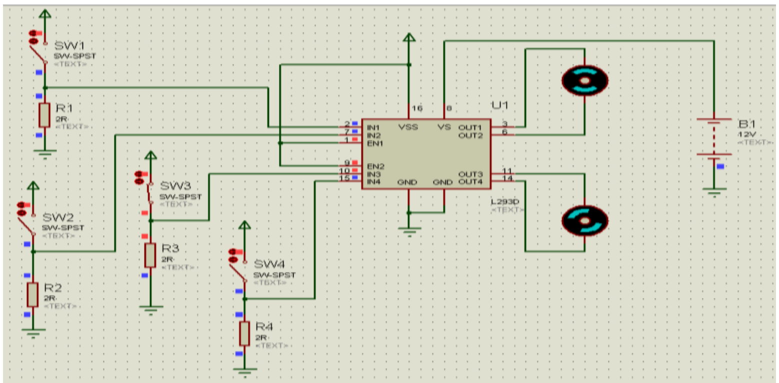

Figure 9. Circuit Simulation for Left Navigation.

Algorithm 5:

```
if(chr == RIGHT)
{ digitalWrite(A0, HIGH); =IN1
digitalWrite(A1, LOW); =IN2
digitalWrite(A2, LOW); =IN3
digitalWrite(A3, LOW); =IN4
delay(50); stop(); }
```

Result: Moved motor right

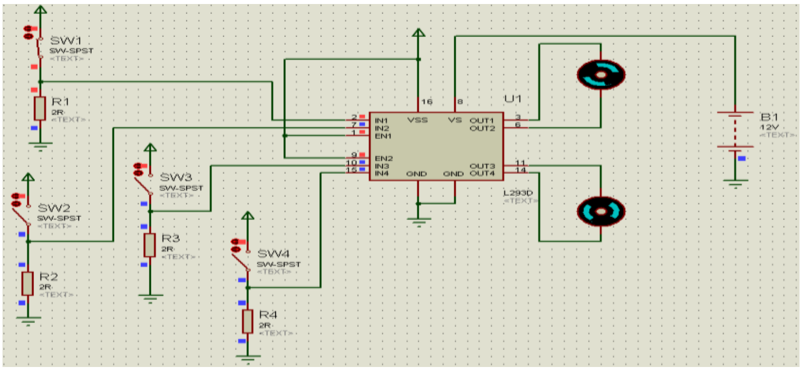

Figure 10. Proteus ISIS Circuit Simulation for Right Navigation.

3.1 Robot Navigation Simulation Study

A simulation study has been carried out for the mobile robot navigation using the Proteus program, which aided in the simulation of the robot mobility in ~~the~~ four directions before the actual design. With the simulation, errors were avoided during the actual design as the simulation was performed successfully. Figure 6 - 10 shows the various algorithms set to drive the motor in four-direction movement; forward, reverse, right and left. From the simulation, we have guaranteed the validity of the robot navigation approach.

3.2 Obstacle avoidance

Following the integration of the physical prototype shown in Fig. 11, a series of extensive experimental tests were performed to assess the robot's mobility whilst completing certain tasks relevant to its purpose such as navigating the environment while avoiding obstacles shown in table 1. Figure 11 shows the robot navigating to avoiding obstacle at 20 cm away.

Table 1. Obstacle detection.

Obstacle	Distance	Action
Solid obstacle	10cm	stop
Solid obstacle	20cm	stop
Solid obstacle	30cm	stop
Solid obstacle	40cm	stop
Solid obstacle	50cm	stop

Figure 11. Obstacle detection.

4 Conclusion

The mobile platform consists of a 4-wheel drive for the robot navigation. The test field consisting of a flat surface was implemented in the lab. A simulation study has been carried out for the mobile robot navigation using the Proteus program, which aided in the simulation of the robot mobility in the four directions before the actual design, with the simulation, errors were avoided during the actual design as the simulation was performed successfully. The wheelbase is able to maneuver around flat ground. Wheels were used in order to decrease complexity, while still providing a means of transport for the robot. The ultrasonic sensing is a good way to sense proximity. Within the human environment the robot could come across many obstacles which make a proximity sensor suitable in detecting obstacles with high level of reliability using the Arduino microcontroller.

The sensor works by measuring the distance to an object using ultrasonic sound waves with the use of transducers to send and receive ultrasonic pulses that relay back information about the proximity of an object. The simulation result shows the various algorithms set to drive the motor in four-direction movement; forward, reverse, right and left. From the simulation, we have guaranteed the validity of the robot navigation approach. For robot navigation in both static and dynamic environments which is real world environment, the Path Planning method such as heuristic-based algorithms search for a solution with good quality while focusing on solution finding time reduction.

References

[1] David, V., & Jiri, K. (2009). General-purpose mobile robotic platform with hybrid power module for educational purpose. IFAC Proceedings Volumes, 42(1), 149-152.

[2] Cha, Y. S., Kim, K., Lee, J. Y., Lee, J., Choi, M., Jeong, M. H., ... & Oh, S. R. (2011). MAHRU-M: A mobile humanoid robot platform based on a dual-network control system and coordinated task execution. Robotics and Autonomous Systems, 59(6), 354-366.

[3] Azeta, J., Bolu, C., Abioye, A. A., & Oyawale, F. A. (2018). A review on humanoid robotics in healthcare. MATEC Web of Conferences 153, 02004. https://doi.org/10.1051/matecconf/201815302004

[4] Costa, C. M., Sobreira, H. M., Sousa, A. J., & Veiga, G. M. (2016). Robust 3/6 DoF self-localization system with selective map update for mobile robot platforms. Robotics and Autonomous Systems, 76, 113-140.

[5] Alipour, K., Robat, A. B., & Tarvirdizadeh, B. (2019). Dynamics modeling and sliding mode control of tractor-trailer wheeled mobile robots subject to wheels slip. Mechanism and Machine Theory, 138, 16-37.

[6] Alipour, K., & Moosavian, S. A. A. (2015). Dynamically stable motion planning of wheeled robots for heavy object manipulation. Advanced Robotics, 29(8), 545-560.

[7] Alipour, K., Daemi, P., Hassanpour, A., & Tarvirdizadeh, B. (2017). On the capability of wheeled

mobile robots for heavy object manipulation considering dynamic stability constraints. Multibody system dynamics, 41(2), 101-123.
[8] Ishii, K., & Miki, T. (2007). Mobile robot platforms for artificial and swarm intelligence researches. In International Congress Series (1301, 39-42). Elsevier.
[9] Scharnagl, J., & Schilling, K. (2016). New Hardware-in-the-Loop Testing Concept for Small Satellite Formation Control Based on Mobile Robot Platforms. IFAC-PapersOnLine, 49(30), 65-70.
[10] Vroegindeweij, B. A., Blaauw, S. K., IJsselmuiden, J. M., & van Henten, E. J. (2018). Evaluation of the performance of PoultryBot, an autonomous mobile robotic platform for poultry houses. Biosystems Engineering, 174, 295-315.
[11] Azeta, J., Bolu, C., Hinvi, D., & Abioye, A. A. (2019). Obstacle detection using ultrasonic sensor for a mobile robot. In IOP Conference Series: Materials Science and Engineering (707, 1, 012012). IOP Publishing.
[12] Ariffin, I. M., Baharuddin, A., Atien, A. C., & Yussof, H. (2017). Real-Time Obstacle Avoidance for Humanoid-Controlled Mobile Platform Navigation. Procedia Computer Science, 105, 34-39.
[13] van Steen, M., Mohapatra, P., & Rangan, P. V. (2014). Wireless technologies for humanitarian relief. Ad hoc networks, *13*(PART A).