CONTENTS

Thanks for:

To complete this report, we sincerely thank the FAST faculty for creating the facilities and learning environment that will serve the project's research and practice.
Furthermore, we especially thank the PhD Le Quoc Huy and his teaching assistant, Nguyen Manh Chien, for your dedicated guidance and for imparting knowledge and experience to help us research and successfully create the product.
Because we do not have enough experience, we cannot avoid mistakes. We look forward to receiving feedback from the teacher to complete the project better.

Thank you!

I. Introduction

This report provides a comprehensive account of the design, construction, and use of an autonomous maze-exploration robot based on Arduino. The robot uses ultrasonic sensors for maze navigation. This material discusses different components, details the methodology of programming and assembling the robot, and identifies the roadblocks faced in the process. The intention is to help us familiarize ourselves with robotics, control systems, and sensor integration.

1. Members:

- **Dinh Ngoc Thinh (leader): coder and report writer**
- **Duong Van Truong: hardware assembly and report writer**
- **Hoang Dinh Hieu: hardware assembly and coder**
- **Tran Trung Chien: hardware assembly**
- **Truong Quang Huy: report writer**
- **Nguyen Tien Hung: main coder**

1.1 Percentage of work contribution

- **Dinh Ngoc Thinh:** 17% - Good
    + Absent 1 session.

    - Working hard, participating actively, and having good ideas for optimizing robot movement.
    - Completing assigned work excellently.
- **Hoang Dinh Hieu:** 20% - Excellent
    - Not absent.
    - Participating actively, optimizing, and adjusting hardware excellently.
    - Completing assigned work excellently.
- **Duong Van Truong:** 17% - Good
    - Absent 2 sessions.
    - Participating positively. Finding ways to adjust the circuit diagram design of the robot.
    - Completing assigned work excellently.
- **Tran Trung Chien:** 15% - Good
    - Absent 2 sessions.
    - Learning the robot's hardware actively and fixing the flaws of the robot.
    - Completing assigned work sufficiently.
- **Truong Quang Huy :** 14% - Good
    - Absent 2 sessions.
    - Participating efficiently and making good contributions in writing the report.
    - Completing sufficiently.
- **Nguyen Tien Hung:** 17% - Good
    - Absent 2 sessions
    - Being the main coder and having a small contribution to the report
    - Completing assigned work sufficiently.

2. Research topic:

The maze exploration robot is one of the well-liked projects in education institutions and all robotics competitions as this robot is multi-mechanisms concerning its fundamental design and programming. The project was to design a mini robot that would find its way in a predetermined maze employing several ultrasonic sensors and an Arduino microcontroller. This report will state the problems and solutions that our team posed and found, as well as describe the function of each component included in the product.

3. Purposes of the Project:

- Design and construct an autonomous robot capable of exploring and navigating a maze.
- Implement obstacle detection and avoidance using ultrasonic sensors.
- Develop programming logic for efficient maze exploration.
- Gain hands-on experience with robotics and sensor integration.

II. Contents:

1. Problem statement:

Navigating through a maze is a classic problem in robotics and artificial intelligence. The challenge lies in developing a robot that can efficiently find its way from the start to the end of a maze while avoiding obstacles. The primary problems addressed in this project include:

- How to detect walls and obstacles in the maze?
- How to implement an algorithm for pathfinding?
- How can robots be ensured to operate autonomously without human intervention?

2. Solutions:

To solve the problem, we designed a maze exploration robot utilizing ultrasonic sensors for obstacle detection and an Arduino microcontroller for processing and decision-making. The robot employs the following strategies:

- Sensor Integration: Using ultrasonic sensors to measure distances and detect walls.
- Pathfinding Algorithm: Implementing a specific wall-following (left-following) algorithm or a balancing algorithm to navigate through the maze.
- Motor Control: Using motor drivers to control the robot’s speed and movement based on sensor inputs.

3. Hardware components

(*) Required components

- 18650 Batteries : Provide power to the robot to operate.
- 18650 Battery Holder: holds the battery and facilitates electricity transmission to the robot’s components.
- MCU Arduino Uno: This will be explained in section 3.3.
- Breadboard: Serves as a test board that allows us to assemble and test electrical circuits without soldering easily.
- Motor Driver L298N: This will be explained in section 3.5.
- Bus Wire: A short wire used in electrical systems to connect and transmit signals between different components in the system.
- Yellow DC Motors & Wheels: This will be explained together with the wheels in section 3.7.
- Ultrasonic Distance Sensor (HC-SR04): This will be explained in section 3.8
- Chassis: This will be explained in section 3.9.
- USB Cable A-B:
- Rocker Switch: used as an ON/OFF switch on the main power supply for Arduino circuit
- Nuts/Screws & Small Copper Piles: Fix the robot's chassis.
- Multi-directional Rollers: Adjust the robot's direction of movement at various angles.

3.1/ 18650 Batteries

These batteries provide the primary power source for the robot. They are rechargeable and have a high capacity, allowing the robot to operate for extended periods. The voltage and current supplied by the batteries must match the requirements of the motors and other electronic components.

Specifications:

Battery type:	18650 Li-ion rechargeable battery
Average Voltage	3.7V DC
Capacity	1200mAh.
Peak continuous discharge current	Up to 4A-8A (depending on each specific battery)
Energy capacity	4.44 Wh (3.7V * 1.2Ah)
Size	18mm (diameter) x65mm (length)
Weight	~45-50g

3.2/ 18650 Battery holder

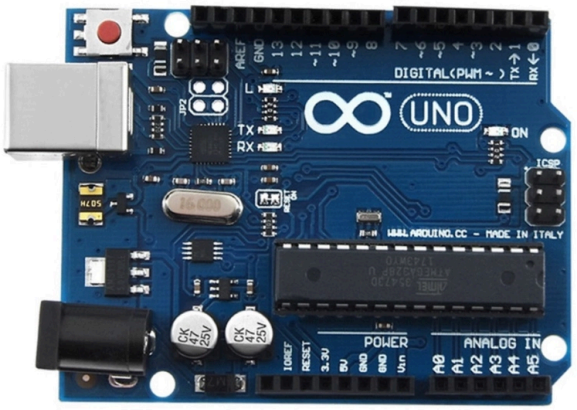
The battery holder securely holds the 18650 batteries in place, ensuring proper electrical contact. It typically has connections for positive and negative terminals, allowing for easy integration into the robot's power circuit. The holder also facilitates easy battery replacement and maintenance.

Specifications:

Compatible Battery	18650 Batteries
Length	76mm (2.98")
Width	41mm (1.61")
Height	19.35mm (0.762")
Wire Length	130mm (5.11")
Weight	13.9g (0.5oz)

3.3/ MCU Arduino UNO

The Arduino UNO microcontroller acts as the robot's central processing unit. It executes the programmed logic, processes input from sensors (like ultrasonic sensors), and sends commands to the motor driver to control the robot's movement. It also handles communication with other components and can be programmed using the Arduino IDE.



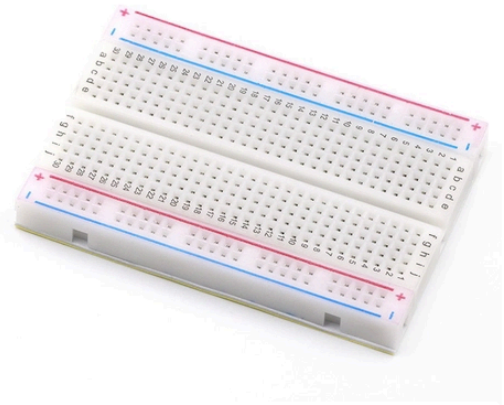
Specifications:

Microcontroller	ATmega328
Operating voltage	5V (Supplied via USB port only)
Recommended input voltage	7-12V
Limit input voltage	6-20V
Operating frequency	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25g
Analog input pins	6
Digital I/O pins	14 (6 hardware PWM pins)
Flash memory	32 kB (ATmega328) with 0.5 kB used by bootloader
SRAM	2 kB (ATmega328)
EEPROM	1 kB (ATmega328)

3.4/ Breadboard

The breadboard is a reusable platform for prototyping electronic circuits. It allows for easy connections between components without soldering. The

breadboard's layout allows for easy adjustments and testing of circuits, facilitating the integration of sensors, motors, and other components.

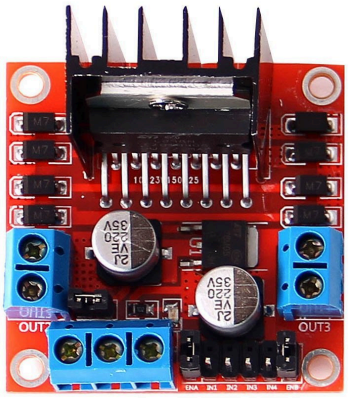


Specifications:

Breadboard Type	Solderless Breadboard
No. of Distribution Strips / Buses	2Bus Strips
Board Dimensions (L x W) - Imperial	3.3" x 2.14"
Total Number of Tie Points	400 Tie Points
No. of Terminal Strips	1 Terminal Strip
Board Dimensions (L x W) - Metric	84mm x 54.35mm

3.5/ Motor Driver Module (L298N)

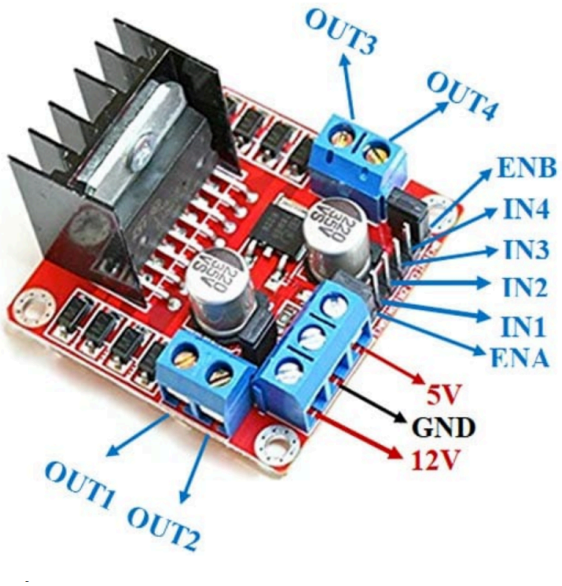
The L298N motor driver module is a powerful tool for managing Direct Current (DC) two-shaft gear motors. This module consists of the L298 motor driver integrated circuit (IC) along with a 78M05 voltage regulator, providing a stable 5V output.



Specifications:

Module controller	2A L298N
Chip controller	Dual H-Bridge L298N
The voltage supplied to the motor (maximum)	46 V
Current supplied to the motor (maximum)	2 A
Logic voltage	5 V
Logic current	0-36 mA
Operating voltage of IC	5-35 V
Operating current of IC	2 A
Maximum power (W)	25 W

Features:



IN1 & IN2	The input pins that control the direction of motor A
IN3 & IN4	The input pins that control the direction of motor B
ENA	activate the PWM signal for motor A
ENB	activate the PWM signal for motor B
OUT1 & OUT2	Output pins for motor A
OUT3 & OUT4	Output pins for motor B
12V	Power supply input for L298N
5V	Power supply for logic circuit inside IC L298N
GND	Ground pin

The L298N module can control a maximum of four or two DC motors. Using L298N means enabling the bidirectional control of movements and speed while navigating through the maze.

3.6/ Bus wire

Bus wires are used to connect various components on the breadboard and to the Arduino. They facilitate the flow of electrical signals and power between different parts of the robot. These wires help in organizing the circuit and ensuring reliable connections.

Specifications:

Length	20cm
Dimension between pins	2.54mm
Number of colors	10 colors

3.7/ Yellow DC Motors and Wheels

These are two DC motors integrated with two wheels. The wheels enable motion forward, backward, and turning in all possible directions, allowing comfortable movement through the tight spaces in a maze.

Specifications:

Operating Voltage	3 V-12 V DC
Current	50mA-500mA (depending on load and voltage)
Gear Ratio	1:48
Power output	0.1-1W
Weight	26 - 29 g
Length	65 - 70 mm
Width	20 - 37 mm
Height	22 mm
Shaft diameter	5 mm
Shaft width	3.5 mm
Shaft length	9 mm
Lifetime	500-1000 hours

3.8/ Sensors

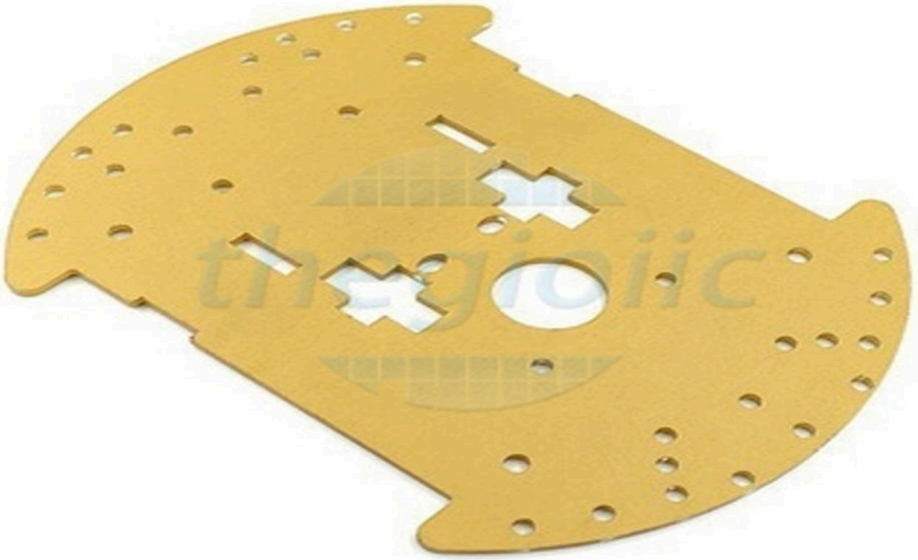
In this project, we use an ultrasonic wave device to determine the direction of movement of the Arduino:

• Ultrasonic Distance Sensor (HC-SR04): Measures distances to walls and obstacles. It emits ultrasound at a 40kHz frequency that travels through the air, the reflected sound is then converted into an electrical signal and transmitted to the main circuit, which triggers the robot's subsequent operations. This device includes 4 categories: VCC, Trig, Echo, and GND.

Specifications:

Operating voltage	5V
Consumption current	10~40mA
Scan angle	<15 degrees
Broadcast frequency	40Khz
Actual measurement distance	2~80cm
Size	43mm x 20mm x 17mm
Signal pin	Echo, Trigger.

3.9/ Chassis



It is a platform structure of the robot that takes responsibility for carrying all components and acting as a body to perform pre-programmed operations. It ensures stability and durability during operation.

3.10/ USB Cable A-B

USB Cable A-B is a USB port wire that is used to connect devices for data transferring. This cable includes two different connectors on both sides:

- USB-A: A rectangular-shaped connector that plugs into the host base
- USB-B: A trapezoidal-shaped connector that is used for the robot

Image:

3.11/ Rocker switch

The rocker switch is a simple on/off switch that controls the robot's power supply. It allows users to easily turn the robot on or off without disconnecting the battery, providing a convenient way to manage power.

Specifications:

Size	10 x 15 x 19mm
SKU	KCD1-101.
On/off switch	6A-250VAC.

3.12/ Nuts/screws & Small copper piles

Nuts and screws are used to secure components to the chassis, ensuring that everything is held firmly in place during operation. Small copper piles (or spacers) may be used to create distance between components or to assist in mounting, helping to prevent short circuits and ensuring proper alignment.

3.13/ Multi-directional rollers

Multi-directional rollers (or omni-wheels) allow the robot to move smoothly in multiple directions without needing to change its orientation. They enhance the robot's maneuverability, making it easier to navigate tight spaces and perform complex movements.

4. Software & Circuit Design

4.1/ Wiring

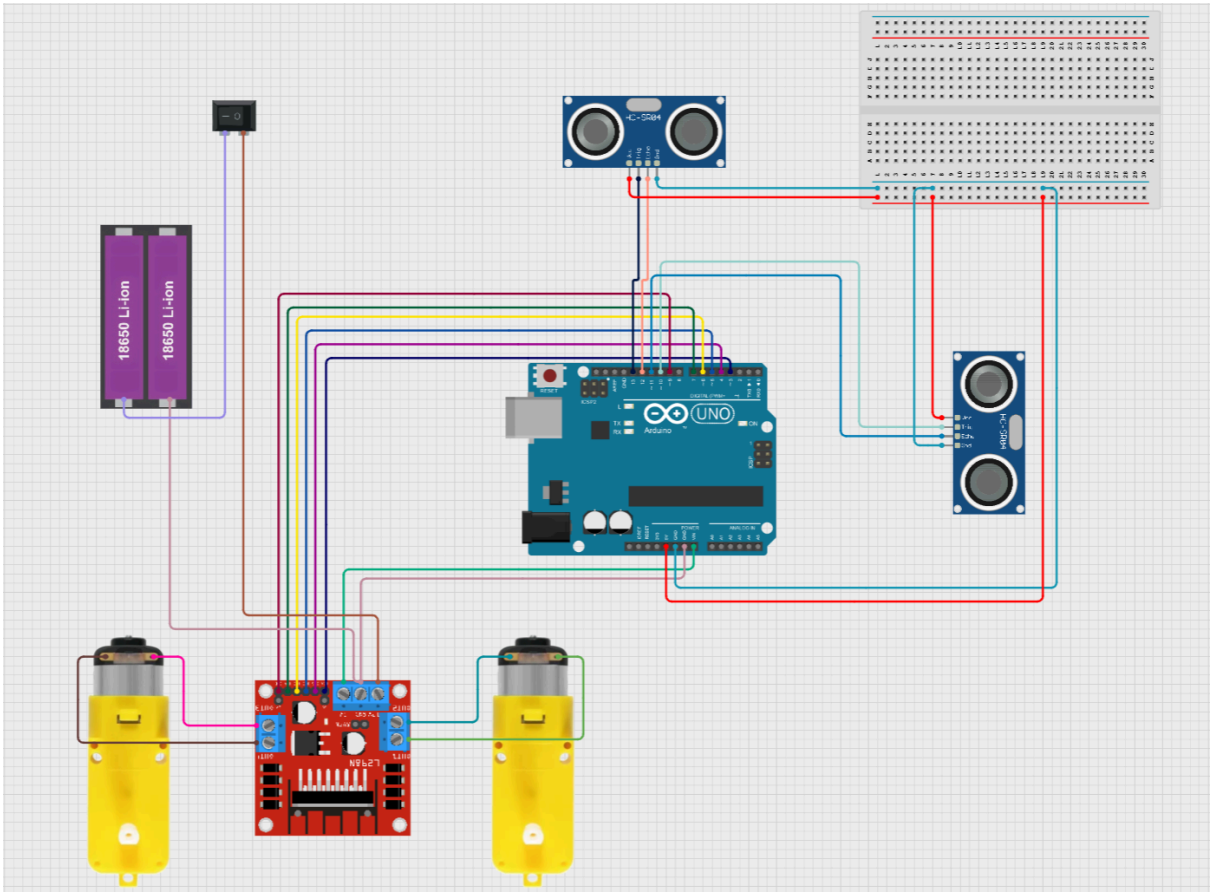
The Wiring Connection is to connect Arduino Uno to DC motors, L298N, and sensors as follows:

- The output ends of the DC Motors are connected to L298N.
- The above L298N inputs are connected with the Arduino digital pins to specify the direction and speed of the motor.
- The ultrasonic sensor gives distance data, which is provided as an input to the Arduino's analog pins.

4.2/ Circuit diagrams and algorithm flowchart:

- Circuit diagram of wiring components.

Image:



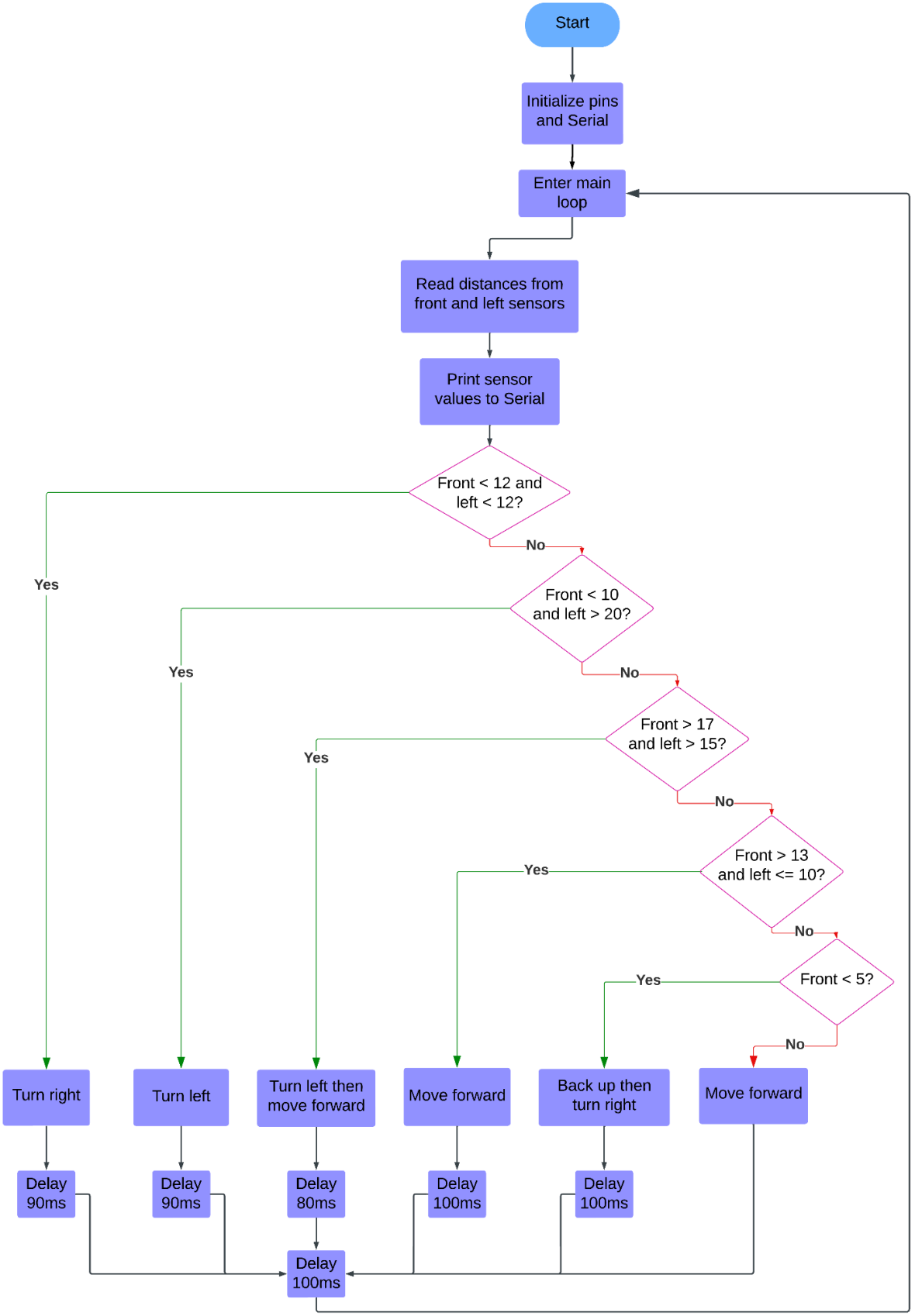
To have a specific view:
https://app.cirkitdesigner.com/project/63b268c5-f938-4fcb-9b4c-f9a279bd2321

Description:

ENA	~3
ENB	~9
IN1	4
IN2	~5
IN3	~6
IN4	7
Left trig	13
Left echo	12

Front trig	~10
Front echo	~11
Left VCC	(+) of breadboard
Left GND	(-) of breadboard
Front VCC	(+) of breadboard
Front GND	(-) of breadboard
(-) of breadboard	GND of Arduino circuit
(+) of breadboard	5V of Arduino circuit
5V of L298N	VIN of Arduino circuit
GND of L298N	GND of Arduino circuit
GND of L298N	(-) of Battery holder
12V of L298N	On/Off switch
OUT1	Right motor
OUT2	Right motor
OUT3	Left motor
OUT4	Left motor

- Flowchart for the left-following algorithm.


Start
Initialize pins and Serial
Enter main loop
Read distances from front and left sensors
Print sensor values to Serial
Front < 12 and left < 12?
Yes
No
Front < 10 and left > 20?
Yes
No
Front > 17 and left > 15?
Yes
No
Front > 13 and left <= 10?
Yes
No
Front < 5?
Yes
No
Turn right
Turn left
Turn left then move forward
Move forward
Back up then turn right
Move forward
Delay 90ms
Delay 90ms
Delay 80ms
Delay 100ms
Delay 100ms
Delay 100ms

To have a specific view:
https://lucid.app/lucidchart/a98918ee-3538-4fe6-8713-0b721e55e0e2/edit?viewport_loc=-5784%2C-3073%2C10567%2C5535%2C0_0&invitationId=inv_c563c4d6-f846-4c29-baec-ececfc13f2bd

4.3/ Code

```
#define ENB 9

#define IN4 7

#define IN3 6

#define IN2 5

#define IN1 4

#define ENA 3


int trigfront = 10;

int echofront = 11;

int trigleft = 13;

int echoleft = 12;


long durationfront, durationleft;

int Ahead  =0, left  = 0, distance;

void setup() {

    delay(1000);

  Serial.begin(9600);

  pinMode(trigfront, OUTPUT);
```

```
  pinMode(echofront, INPUT);
  pinMode(trigleft, OUTPUT);
  pinMode(echoleft, INPUT);
  pinMode(ENA, OUTPUT);
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);
  pinMode(ENB, OUTPUT);
}
void Forward() {
  analogWrite(ENA, 125);
  analogWrite(ENB, 120);
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}
void BackUp() {
  analogWrite(ENA, 90);
  analogWrite(ENB, 105);
```

```
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
}
void LeftTurn() {
  analogWrite(ENA, 200);
  analogWrite(ENB, 100);
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
}
void RightTurn() {
  analogWrite(ENA, 130);
  analogWrite(ENB, 190);
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}
```

```
int readDistance(int trigPin, int echoPin) {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  long duration = pulseIn(echoPin, HIGH);
  return duration * 0.034 / 2;
}
void loop() {
  Ahead = readDistance(trigfront, echofront);
  left = readDistance(trigleft, echoleft);
  Serial.print(" front: ");  Serial.print(Ahead) ;  Serial.print(" cm");
  Serial.print(" left: ") ;  Serial.println(left);  Serial.print(" cm");
  if (Ahead < 12 and left  < 12)
  {
    RightTurn();  delay(90);
    Serial.print("  TURN RIGHT");
    }
    else if(Ahead<10 and left >20 )
  {
```

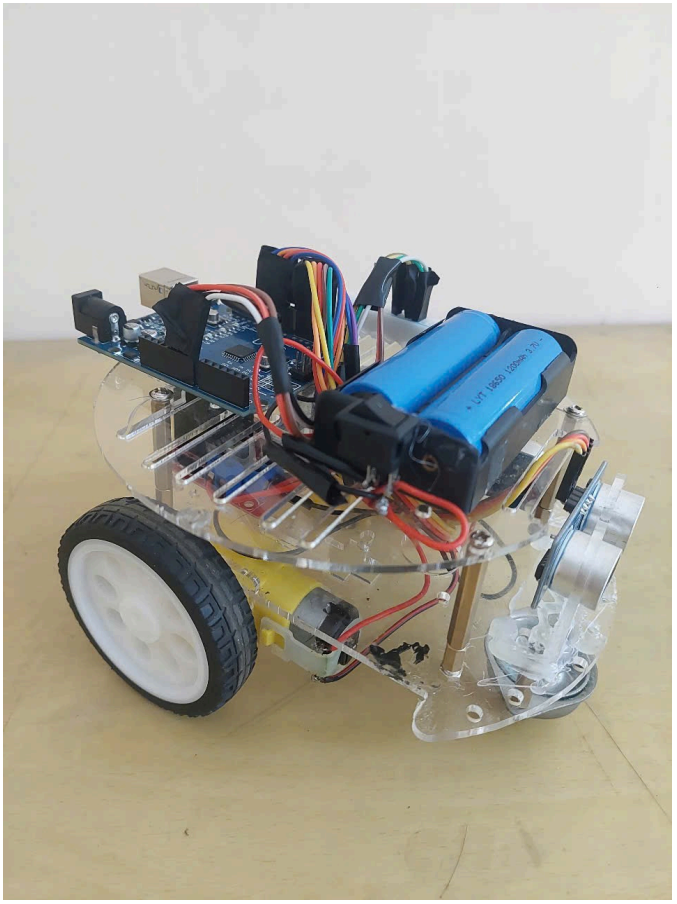
```
 LeftTurn();      delay(90);
 Serial.print("  TURN LEFT");
 }
 else if (Ahead>17 and left >15)
{
 LeftTurn();      delay(80);
 Serial.print("  TURN LEFT");
 Forward();
 }
 else if (Ahead>13 and left<=10)
{
 Forward();
 Serial.print("  GO STRAIGHT");
 }
  else if (Ahead<5)
{
 BackUp();       delay(100);
 Serial.print("  MOVE BACK");
 RightTurn(); delay(100);
 }
  else
```

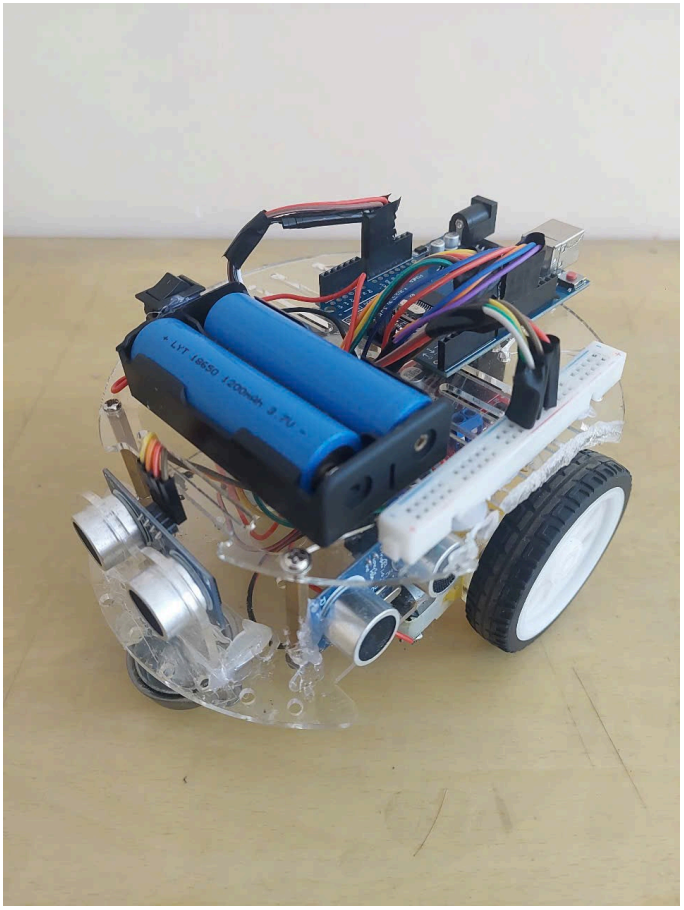
```
  {
    Forward();
    Serial.print("  GO STRAIGHT");
    }
  delay(100);
}
```

4.4/ Operating principle of the device

The robot operates autonomously by processing real-time data from ultrasonic sensors. It identifies obstacles, calculates path direction, and controls motor movements accordingly.

5. Robot products:





III. Conclusion and Lessons Learned

This project provided valuable insights into robotics, sensor integration, and programming principles. The challenges, such as inconsistent sensor readings, taught us the importance of precise calibration. The robot's performance highlights the potential for enhancements, such as:

- Improving algorithms for more complex mazes.

- Assembling the robot's components in a streamlined manner to ensure safety during movement. For instance, the sensors should be positioned securely within the chassis to prevent them from getting caught on bends, and the wires should be organized neatly to avoid any risk of electrical short circuits.

- Adjusting the data parameters to match the sensor to avoid misreading data or movement commands.

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Ball Transfer Caster 2-3/4in x 2in Oblong Flange | HB-OBLONG