AL-NAJAH NATIONAL UNIVERSITY

FACULTY OF ENGINEERING

COMPUTER ENGINEERING DEPARTMENT

GRADUATION PROJECT

Maze Solver Robot

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1 Acknowledgement

First and foremost, we want to express our sincere gratitude for the successful completion of the maze-solving robot project. We are grateful to God Almighty for granting us wisdom and determination to overcome challenges along the way. The success of this project was a result of everyone's collective efforts and shared commitment towards achieving it. Certainly, each person played an important role in contributing their skills at different stages. I extend my deepest appreciation to our project supervisor, Dr.Saed Tarabiah, for providing invaluable guidance and unwavering support throughout the development process. His expertise and constructive feedback significantly enhanced the robot's maze-solving capabilities.The last but not least is acknowledging tremendous support from families friends which motivated us whenever needed energy boost through challenges encountered on this rigorous journey.
In conclusion, all contributions mentioned above were vital toward accomplishing such complexities together - heartfelt thanks!

2 Disclaimer

Majdy Sabra and Naser Tayeh from An-Najah National University's Faculty of Engineering's Computer Engineering Department authored this study. Other than editorial adjustments, it has not been amended or rectified as a consequence of assessment, and it may contain language and content mistakes. The opinions represented in it, as well as any results and recommendations, are exclusively those of the students Majdy and Naser. An-Najah National University assumes no responsibility or liability for the outcomes of using this study for a purpose other than what it was commissioned for.

3 Abstract

In the last five decades, cutting-edge robotic technology has become indispensable across various industries, delivering unparalleled precision in tasks spanning industrial production, healthcare, transportation, and security. Nevertheless, specialized robots tailored to specific functions often demand intricate technical support and incur substantial maintenance costs. This project unveils a highly adaptable maze-solving robot, equipped with three Ultra Sonic sensors, three Sharp IR sensors, 4 micro switches , a module IR sensor to detect end of maze , an LCD for measurement, two DC motors, an Arduino Mega, and a motor driver.This robot is meticulously crafted to adeptly navigate complex 3D mazes. Collected data from an array of sensors is seamlessly transmitted to an Arduino micro controller [1], which takes charge of wheel movement direction after executing essential operations on the received information.

The robot excels in traversing and conquering 3D mazes, guided by a fundamental principle: detecting its present location and making informed decisions for subsequent moves.This undertaking introduces a sophisticated three-wheeled robot featuring dual operational modes. Leveraging a singular Arduino Mega micro controller and an array of sensors, including Sharp IR, IR, and switches for hit detection, the robot exhibits versatile capabilities. Its primary objective remains the navigation of predetermined paths on flat surfaces, complemented by a dedicated emphasis on obstacle avoidance.

4 Introduction

Building a moving robot is a difficult proposition because it demands dealing with many selections before beginning the construction process, like its position, wheels, and torque, the type of motor drive circuit, the ability of the motor to hold all the components and move, in addition to take correct value from the sensors and other matters.

4.1 Problem

Embracing adaptability and overcoming challenges has been an inherent aspect of human nature, leading to enhanced comfort and luxury in both individual and communal lives. Technological advancements have further empowered us to confront and adapt to various challenges, especially in the realm of transportation within corporations. The integration of robotics offers a significant stride toward fully automating transportation systems, thereby amplifying efficiency, reliability, and reducing the workforce required. This robot, equipped with advanced features like IR sensors, Sharp IR sensors, and an Arduino Mega controller, embodies this technological evolution.

Potential applications for the maze-solving robot encompass navigating complex environments to efficiently find optimal paths and solve intricate mazes. Its capabilities are tailored for specific tasks, such as exploring and mapping maze structures, making it invaluable in various scenarios. The robot's aptitude for precise navigation and obstacle avoidance makes it an ideal solution for intricate maze-solving challenges, showcasing its potential in research, educational applications, and entertainment venues featuring maze-based activities.

Outlined below are the specific aims and applications aligned with the capabilities of the maze-solving robot:

1. Efficiently navigate and explore intricate maze structures, serving as a valuable tool for research, educational applications, and entertainment venues.
2. Specialized in solving maze challenges,
3. Demonstrate seamless obstacle avoidance capabilities during maze-solving missions, ensuring smooth and efficient navigation through challenging environments.

4.2 Objective

In this section, we delineate the objectives, purpose, and aims of our maze-solving hardware project. The primary goal of this work is to design and implement an efficient hardware system capable of autonomously navigating through a maze environment.

1. Strategically decide on the most suitable tools, including controllers, ICs, motors, etc., for the entirety of the maze-solving robot project before initiating the construction phase.

2. Autonomous Maze Navigation , we develop a hardware solution that enables an autonomous robot to navigate through a maze environment without human intervention and we implement algorithms and control mechanisms to ensure real-time decision-making for optimal path finding.

3. Sensor Integration and Processing , to provide the hardware with the necessary environmental awareness.

4. Efficiency and Speed , we achieve that by design the hardware system with a focus on efficiency to enable quick and precise maze traversal.

These objectives collectively aim to propel the maze-solving robot toward achieving optimal performance and functionality in diverse maze-solving scenarios.

4.3 Importance of the robot

Our maze-solving hardware project contributes significantly to educational and research domains

5 Constraints, Standards and Earlier coursework

5.1 Constraints

- Sharp IR sensor Range from 10cm - 80cm only , and this become a problem in the large distance , so it does not detect it due to that we combine the Ultra sonic sensors.

- Sharp IR give the same result for small distance(less than 10cm) and for large distance (more than 80cm) , and that appear in the following graph[figure 1] :

- Ultra sonic sensor measure big distance only.

- Sharp-IR measure close distance only.

- Dealing with a new algorithm.

- The big size of the robot requires a big maze.

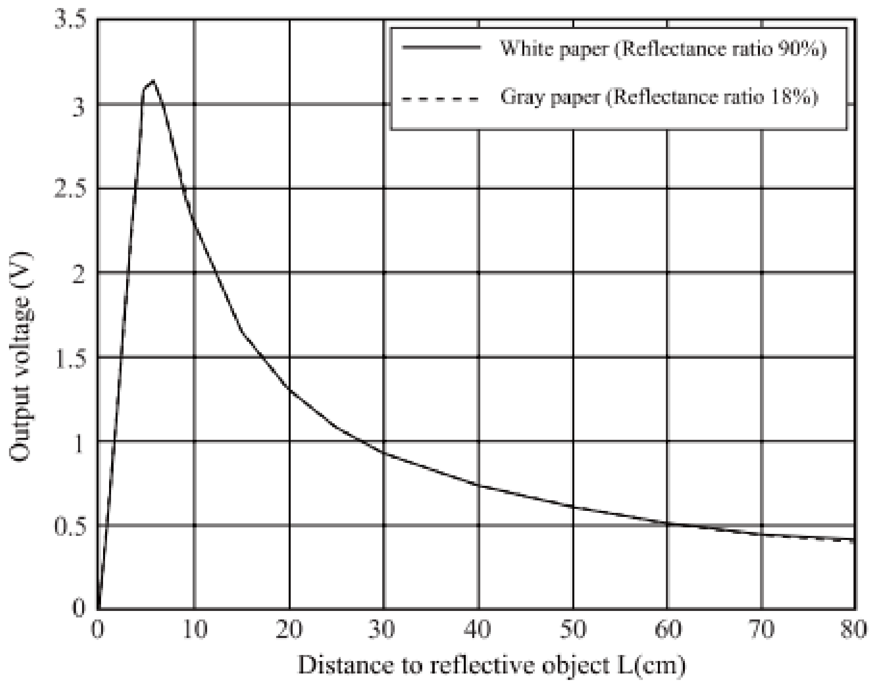

Figure 1: Sharp IR output voltage

- lack of ability to provide a stepper motor(smallest size).
- lack of ability to provide a Ladar.

5.2 Standards and Specifications

In this report section , we will explore the engineering standards applied to the design , providing insights into the careful consideration of each component. The integration of Arduino as the central control unit, coupled with various sensors and motors, highlights our commitment to creating a robust and intelligent robotic system.As we delve into the standards and design considerations, the focus will be on ensuring the reliability, safety, and optimal performance of the maze-solving robot across different scenarios , here is the Engineering standards relevant to our maze-solving robot project :

- IEC 60947-5-2 - Limit Switches:Specifies requirements for the performance, testing, and use of limit switches, ensuring accurate detection of robot movements within the maze.
- IEC 60950 - Safety of Information Technology Equipment:Specifies safety

considerations for electronic equipment, providing guidelines for the safe integration and usage of components like Arduino and LCD in the maze-solving robot.

- Maze Solving Algorithm specs : The Wall Follower Algorithm, also known as the Right/Left Hand Rule, is a heuristic algorithm rather than a standardized protocol. It is a method used in maze-solving where a robot follows the right or left wall of the maze, making turns based on a predefined rule. There isn't a specific industry-standard or formal specification for this algorithm, as it's more of a conceptual approach to maze-solving.

5.3 Earlier coursework

It was essential for us to attend a few courses that play main role on increasing our knowledge and accomplish this project.

- robotics movement.
- Arduino programming.
- Maze solving Algorithm.

6 LITERATURE REVIEW

This area highlights distinctive strategies utilized by analysts on the same theme, and it also gives a written survey of the current innovations that are available to construct human and line follower robots.

In the context of a maze-solving robot, a crucial technique entails employing wall-following methods to determine the robot's position like the ladar. It is important to emphasize that this strategy depends on the deployment of premium and costly components. The adoption of lower-quality components can result in significant challenges, such as inaccuracies in detecting the actual distance to the walls and poor sensitivity of the infrared sensors. To address this issue, we have experimented with integrating sharp infrared sensors into the system.

Ultrasonic sensors, characterized by their cost-effectiveness and resilience in noisy environments due to their reliance on acoustic principles, exhibit limitations in precision and range compared to laser sensors. Ultrasonic sensors may struggle with precision due to surface reflectivity and face challenges in long-range measurements. Additionally, their integration with radio frequency (RF) technology for synchronization can contribute to increased costs.

In contrast, laser sensors, leveraging focused beams of light, offer higher precision, longer range, and resilience to environmental factors. Although laser sensors tend to be more expensive, their versatility in diverse conditions, faster response times, and superior performance in industrial and outdoor settings make them a preferred choice for applications where precision and extended range are critical considerations.

Ultimately, the choice between ultrasonic and laser sensors depends on specific application needs, budget constraints, and the environmental conditions in which they will operate.

Several notable maze-solving robots showcase the ingenuity of their creators in developing autonomous systems for navigating complex environments. In the realm of micromouse competitions, various teams and individuals contribute to the creation of small maze-solving robots. These micromice often incorporate infrared or ultrasound sensors for wall detection and boast lightweight, compact designs to swiftly navigate tight spaces. Another impressive example is Min4pi, crafted by a team at Tohoku University in Japan. Employing a blend of infrared sensors and advanced algorithms, Min4pi adeptly maneuvers through mazes, prioritizing compact design and precise control mechanisms.

Switzerland's Swiss Federal Institute of Technology in Lausanne (EPFL) introduces MazeRunner, a hexapod robot designed to conquer three-dimensional mazes. Equipped with a 3D camera and inertial measurement unit, MazeRunner showcases innovative design principles, using multiple legs for stability and adaptability across different terrains. Additionally, Robotino, created by the German company Festo AG and Co. KG, stands out as a mobile robot armed with laser range finders, cameras, and infrared sensors. Emphasizing modularity, Robotino allows users to customize the robot for specific tasks, showcasing a versatile approach to maze-solving applications. In lecture reviews, these robots highlight the diverse sensor technologies, intelligent algorithms, and careful design considerations that propel the field of autonomous navigation forward. Understanding the practical applications and challenges faced by these robots provides valuable insights into the ever-evolving landscape of maze-solving robotics.

In this report we built a maze solving robot that uses both sharp-IR and Ultrasonic sensor to provide the most accurate data due to lack of resources.

7 Methodology

7.1 Hardware parts :

7.1.1 Overview

Here we will talk about hardware components we used :

- Arduino Mega
- DC motors
- A pair of wheels
- L298N Motor Driver Module
- Connecting wires
- 3 Ultrasonic Sensor(HC-SR04)
- 3 Sharp-IR sensor
- LCD
- 4 switch
- IR for color
- LED's
- buzzer
- power supply

7.1.2 Description

In this section we will talk about each of the hardware components that we used:

1. Controllers

   - Arduino Mega

     It is a microcontroller that has 16 analog inputs as shown in [figure 2] . It has also 54 digital output/input pins (15 of them can be used as PWM).In addition , it contains 4 UARTS , and a USB connection. It's basically used for a black line follower robot that is capable of stopping in front of an obstacle or reaching the end of the route and then it communicate with H-bridge to control the direction and speed of the motors.

Figure 2: Arduino mega 2560

- Ultrasonic Sensor

  An ultrasonic sensor is a device that uses sound waves to detect the distance to an item. It will determine the distance by emitting a sound wave at a specific frequency and listening to the wave when it returns. Because the reflected sound ave may divert from its course and not be received by the ultrasonic sensor, the ultrasonic sensor will be unable to identify some things, look at [figure 3].

Figure 3: Ultrasonic Sensor

- IR sensor
  The infrared (IR) sensors are made up of infrared (IR) LEDs and photodiodes. The IR LED is referred to as a photoemitter, while the IR photodiode is referred to as a receiver. The LED's infrared light hits the surface and is reflected back to the photodiode. The photodiode then produces an output voltage proportionate to the reflectance of the surface, which is high for a bright surface and low for a dark surface, see [figure 4].

Figure 4: IR sensor

2. Motors

- L298N Motor Driver:
  It consists of two DC motors can be controlled concurrently by a dual H-Bridge motor driver. With a peak current of up to 2A, the module can operate DC motors whose voltages range from 5 to 35V , see [figure 5].

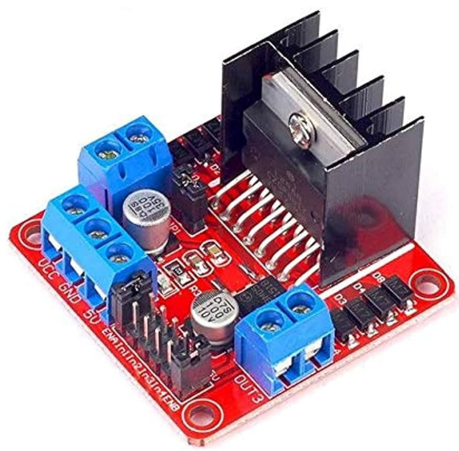

Figure 5: L298N Motor Driver

- Dc Motors with wheels We use 12V DC motors for robot movement (12V 60RPM 25mm High Torque DC Gear Motor Kit with 65mm Plastic wheel, n.d.) , see [figure 6]

Figure 6: Motor

3. Sharp-IR

- Sharp-IR
  IR (Infrared) sensors are a family of proximity sensors manufactured by Sharp Corporation. These sensors use infrared light to detect the distance between the sensor and an object. They are commonly used in robotics, automation, and various electronic projects where the measurement of distance or proximity is required , see [figure 7].

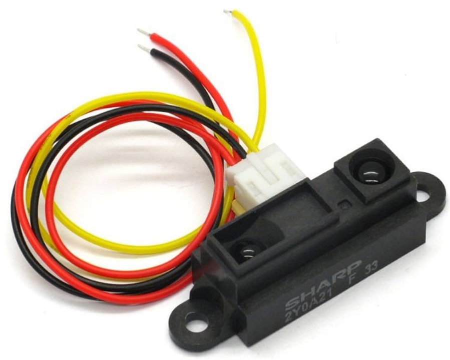

Figure 7: Sharp-IR sensor

- LCD We use LCD to give us the values of the sensors in real time , see [figure 8].

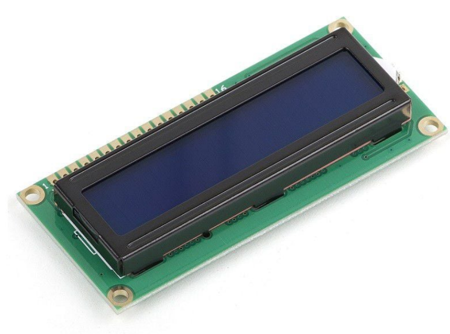

Figure 8: LCD

4. Switch's

- switch's
  The switches used to indicate that the robot hit a wall or if it was stuck at some point. see [figure 9]

Figure 9: macro switch

- Led used as a flag when the robot finish , see [figure 10].

Figure 10: Led

5. Buzzer

- Buzzer
  indicate that the robot finish the maze , see [figure 11].

Figure 11: Buzzer

- power supply used to power the whole robot , see [figure 12]

Figure 12: Led

7.1.3 Hardware Development

Building the robot's body : we started with creating the base for the robot then connect it with the motors and checked that it it balanced. , see [figure 13]

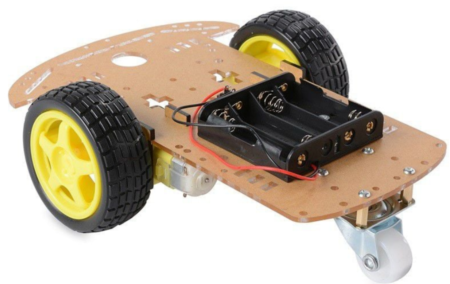

Figure 13: The earliest steps of creating this project

We connect ultrasonic sensor and IR Sensor, LCD and all the othe component to the robot , as shown in [figure 14 , figure 15]

7.1.4 Overall Design

The final result for the robot as shown in figure.15 https://www.overleaf.com/project/65a98d0bc8eb9a10a2de94

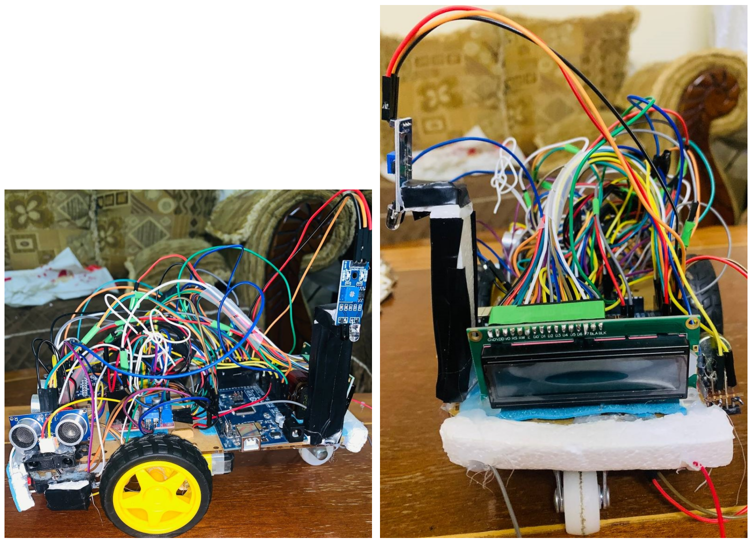

Figure 14: The final result for Maze solver Robot

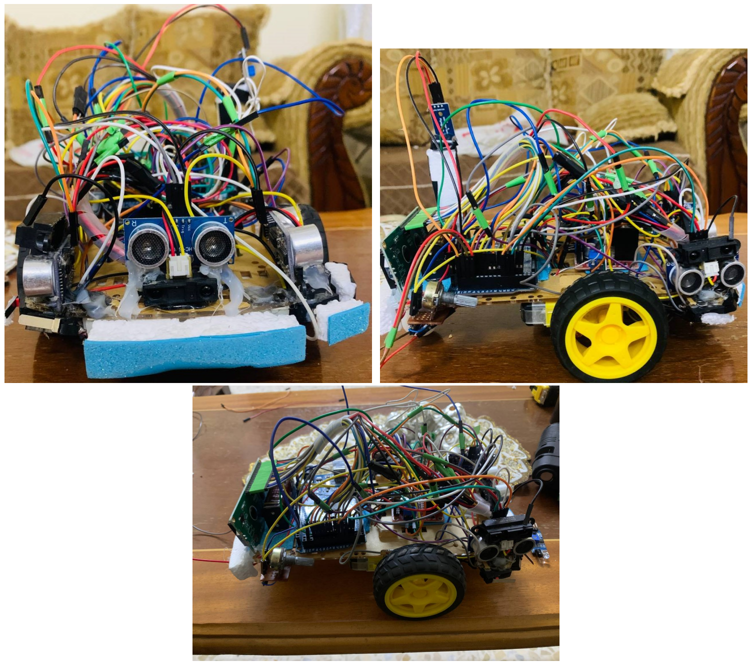

Figure 15: The final result for Maze solver Robot

7.2 Methods and techniques:

- This circuit for the maze solving algorithm , see [figure 16]

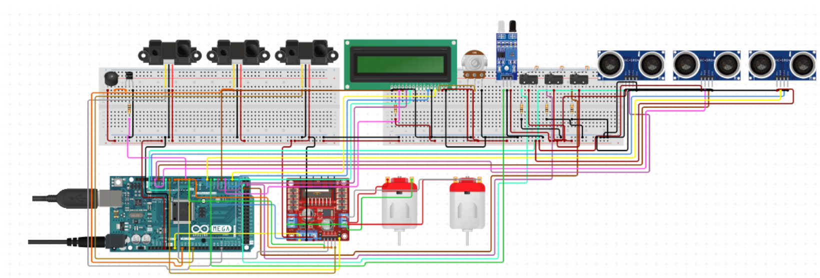

Figure 16: a summary of the Hardware components

- Overview : The wall follower algorithm is a popular technique used to navigate and solve mazes. It's a simple yet effective approach that involves following a wall (either the left or right wall) throughout the maze until the destination is reached [2]. The algorithm is based on the idea that as long as you keep a hand on the wall and continue walking, you will eventually find the exit.[3] Here are the general steps of the wall follower algorithm.

- Select a Starting Point: Begin at a specific point in the maze.
- Choose a Wall to Follow: Decide whether to follow the left or right wall (in our case we chosed left wall)
- Move Forward: Move forward while keeping the chosen wall adjacent to you.
- Wall Following Rules: If there is an opening on the side with the chosen wall, turn in that direction. If there is a wall on both sides, turn 180 degrees. If there is a wall on the side opposite to the chosen wall, continue moving forward.
- Repeat Until Exit is Found: Continue these steps until you reach the exit or the desired destination.[4]

here is the FSM for the Left wall follower algorithm that we used , see [figure 17] :

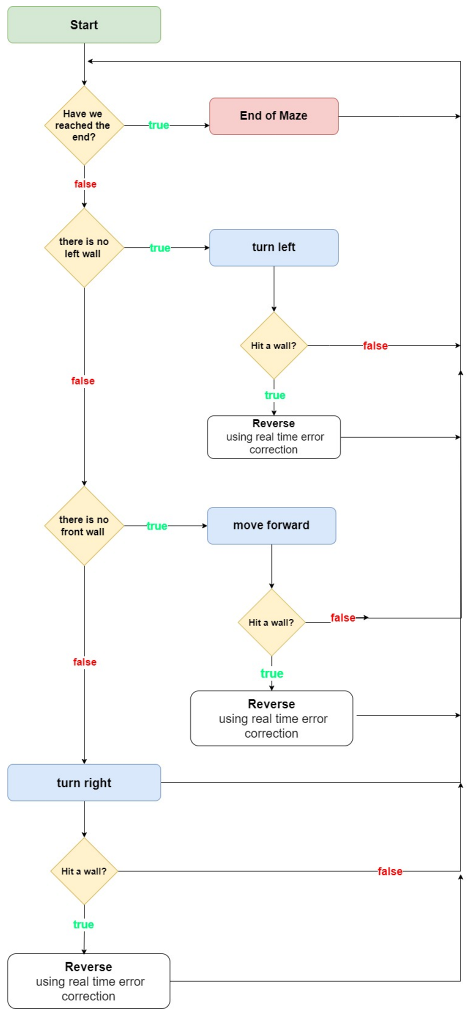

Figure 17: left wall follower

this is one of the mazes that we applied the algorithm on it , [figure 18] how well a robot moves around depends on how accurately it measures

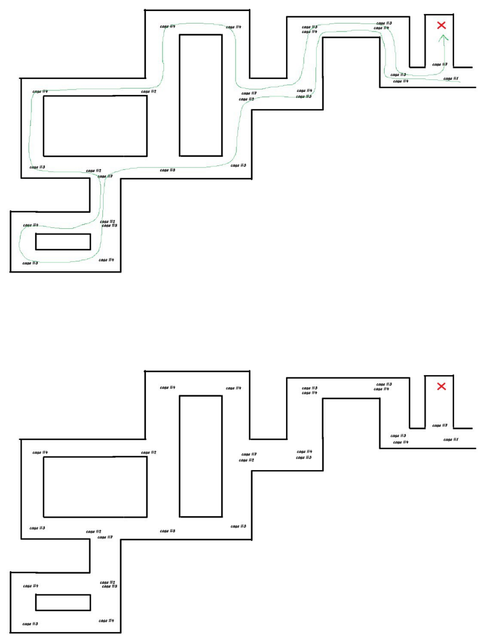

Figure 18: Maze

distances using its sensors. Two types of sensors, ultrasonic and Sharp IR, are like the robot's eyes for figuring out distances. They help the robot know where things are around it. When we use these sensors in maze-solving programs, it's like giving the robot a smarter brain.

- Ultrasonic Sensors:Imagine the robot using sound waves to see how far things are. It sends out sound and listens for it to bounce back. This helps the robot avoid hitting things and decide how fast or slow it should move , see [figure 19].
  - Finding Obstacles: If the robot senses something in its way, it knows to change its path, like going around an obstacle[5].
  - Measuring Distance: By figuring out how far things are, the robot can decide how to move—maybe slow down if something is close or speed up if it's far away. we use the following equation to calculate the distance[6] : as shown in equation (1)

$$Distance = \frac{1}{2} \times SpeedofSound \times RoundtripTime$$

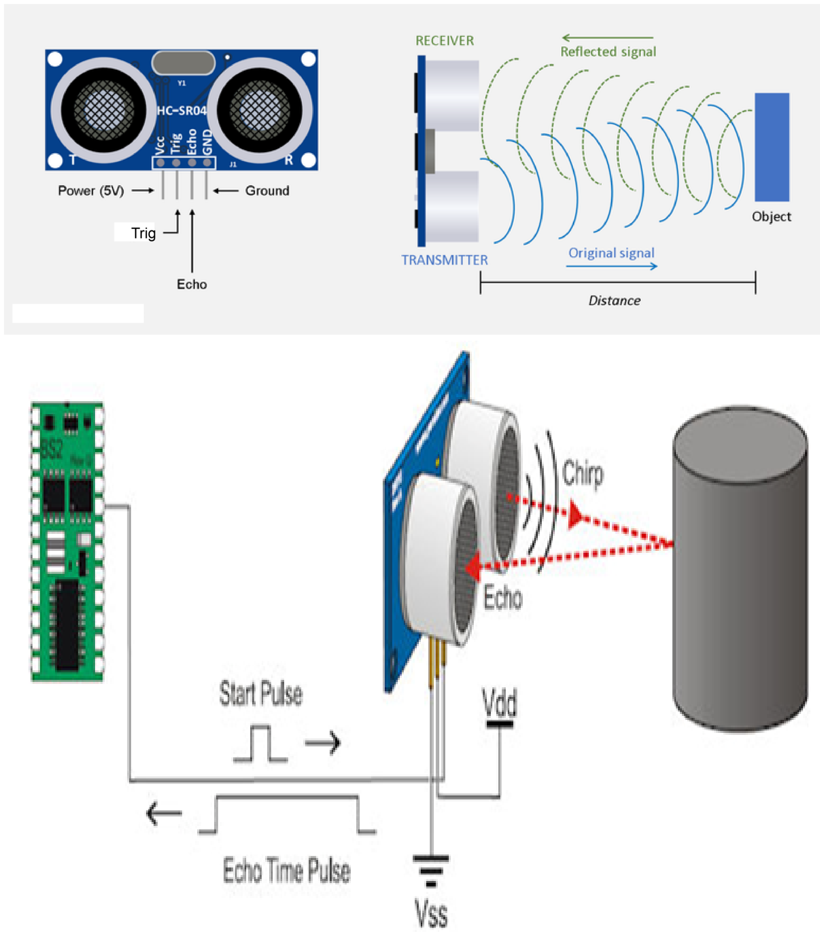

Figure 19: Working Principle of Ultra Sonic

– Sharp IR Sensors: Now, picture the robot using special light to see distances. It sends out light and sees how much comes back. This helps the robot understand the shapes of things in front of it. see [figure 20]

  ∗ Detecting Surfaces: The robot can tell if it's facing a wall or an open space by how much light comes back.
  ∗ Checking Distance: Just like with sound, it uses this information to move precisely and avoid bumping into things., here is the equation we used : (A and B are calibration constants specific to the sensor model , Voltage is the analog voltage output from

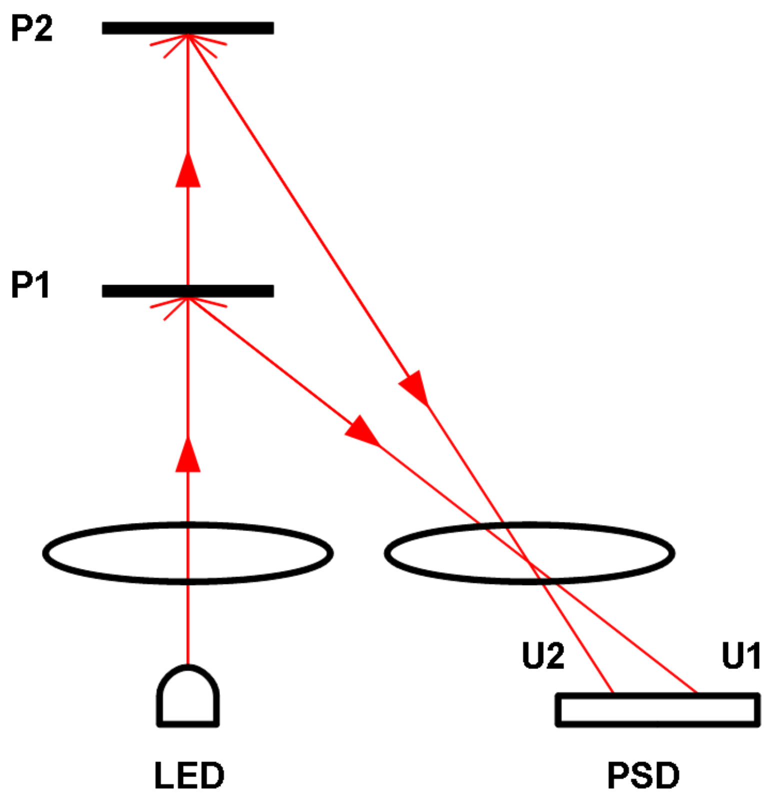

Figure 20: Working Principle of Sharp IR

the Sharp IR sensor.) , as shown in equation (2)

$$Distance = \frac{1}{A \times Voltage + B}$$

This mix of sensors in the robot's brain is like having super-smart eyes and ears. It helps the robot make the best decisions while moving around, especially in tricky mazes. So, by using ultrasonic and Sharp IR sensors together, the robot becomes a maze-solving champ!

8 Result and Discussion:

The maze-solving robot project presented a comprehensive integration of hardware and software components to create an autonomous system capable of navigating through intricate mazes. The success of the project was evident in the robot's efficient path finding, and adaptability to varying maze complexities. The combination of infrared sensors, ultrasonic sensors to the robot's ability to detect walls, avoid obstacles, and measure distances accurately. The implemented software algorithm, incorporating concepts such as depth-first search and PID control, played a pivotal role in the robot's decision-making process, enabling it to make real-time adjustments and successfully reach the maze's endpoint. Despite encountering challenges and limitations related to sensor accuracy and occasional misinterpretation of maze features, the project's outcomes showcased promising results. Future enhancements, including the incorporation of machine learning techniques and improvements in sensor calibration, provide exciting possibilities for advancing the capabilities of maze-solving robots in real-world applications.

9 Conclusion and recommendations:

After building this robot, we gained a lot of skills:

- How to construct the car's hardware.
- Dealing with all configuration and setting for Arduino and LCD.
- Dealing with several hardware components:IR Sensor,ultrasonic Sensor.
- Testing the vehicle to reach a smooth and suitable movement.

10 Future work

Most of the useful features were identified during the development of the maze solver robot, and many of them were implemented. However, due to time constraints and other factors, some of these cannot be included. So, in summary, the development features are as follows:

- Path Memory and Storage.
- Dynamic Path Adaptation.
- Machine Learning for Path Prediction .

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