© December 2023| IJIRT | Volume 10 Issue 7 | ISSN: 2349-6002

Intelligent Robot- Using Wall Following Algorithm

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F.Y.B.Tech Students' Engineering Design and Innovation (EDAI2) Project Paper, SEM 2 A.Y. 2022-23 Vishwakarma Institute of Technology, Pune, India

Abstract— The study for this research paper focuses on creating an intelligent robot inspired by the concept of the Micromouse. The goal is to create a robot that can solve mazes and perform advanced autonomous navigation, similar to the Micromouse but with more sophisticated characteristics. Here, we are developing the WALL FOLLOWING ALGORITHM. This study examines the design and implementation of a intelligent robot that uses a wall-following algorithm to navigate and solve mazes on its own. It evaluates how well the wall-following algorithm enables the robot to navigate through challenging maze layouts.

Keywords—Intelligent robot, micromouse, wall following algorithm, maze solving.

I. INTRODUCTION

The exploration of intricate mazes has long captivated human imagination, presenting challenges that extend beyond mere physical navigation. With concealed dead ends and labyrinthine pathways, mazes have been historically intertwined with entertainment and cognitive pursuits. This research focuses on maze-solving robots, specifically a three-wheeled robotic platform equipped with strategically placed ultrasonic sensors. This amalgamation of robotics and maze-solving creates a captivating intersection of technology, problem-solving, and real-world applications.

The maze, envisioned as a network of walls, serves as the backdrop for our exploration into robotics ingenuity. Imbued with mystery, the maze becomes an ideal arena for our intelligent robot, introducing riddle-solving elements into algorithmic challenges. The dynamic interaction between the robot and the maze embodies the essence of problem-solving, transforming the conventional perception of a physical puzzle into an interactive and engaging platform for technological innovation.

The allure of maze-solving peaks when coupled with autonomous robots armed with algorithms designed to unravel enigmatic paths. Drawing inspiration from micro-mouse robots, our project employs a simplified yet effective wall-following algorithm. Prioritizing the left side, this algorithm enables the robot to navigate the maze by closely tracking its left walls and making strategic decisions at each juncture.

As we embark on this exploration, it is essential to contextualize the significance of maze-solving robots within the broader landscape of real-world applications. Beyond mere amusement, these robots find practical utility in domains such as search and rescue operations, environmental monitoring, and automated logistics. The ability to autonomously navigate complex environments showcases the versatility of maze-solving robots, positioning them as valuable assets where human access may be limited or impractical.

As we navigate through the labyrinth of our research, it is paramount to recognize the inspiration drawn from micro-mouse robots. These diminutive marvels, though physically small, carry a colossal impact on the field of robotics. Our robot's simplified wall-following algorithm pays homage to these principles, embodying efficiency and innovation in a compact yet powerful package.

This research paper seeks to unravel the intricacies of our intelligent robot, shedding light on the technical nuances of the wall-following algorithm and its application in maze-solving. By delving into the convergence of robotics, algorithmic intelligence, and real-world problem-solving, we aim to contribute to the evolving landscape of intelligent robotic systems and their diverse applications.

II. METHODOLOGY

This segment elucidates the procedural framework employed in the development of a maze-solving robotic system utilizing an Arduino Uno microcontroller, interfaced with a Motor Driver Shield (L293D), in conjunction with three HC-SR04 ultrasonic sensors, two battery-operated motors, a caster wheel, and a dedicated power supply. These components are methodically amalgamated onto a compact Medium-Density Fiberboard (MDF) chassis, forming the foundational architecture of the maze-solving apparatus.

The delineation encompasses a multitude of intricacies, commencing with the hardware configuration, where precise spatial arrangements and interconnections ensure optimal operational synergy. The subsequent phase involves motor control, whereby the Arduino Uno orchestrates the synchronized motion of the robotic motors via the Motor Driver Shield, thereby imparting navigational acuity to the system.

Ultrasonic sensor integration is pivotal, constituting the sensory apparatus of the robotic entity. Its deployment involves both the physical allocation of HC-SR04 sensors and the algorithmic calibration of data acquisition parameters. The Wall-Following Algorithm, an integral facet of the system's computational framework, governs the robot's decision-making process during maze traversal, enabling adaptive responses to labyrinthine configurations.

The labyrinth, conceived as a controlled experimental environment, necessitates meticulous design considerations. Calibration procedures ensue, refining sensor readings to align with the idiosyncrasies of the maze, thus facilitating judicious decision-making in real-time navigation scenarios.

Testing procedures, conducted with methodical rigor, encompass diverse labyrinthine scenarios, thereby substantiating the system's adaptability and responsiveness. Decision-making scenarios are introduced to evaluate the robot's capacity for informed navigational choices within the dynamically evolving maze.

Performance metrics serve as quantitative evaluative benchmarks, scrutinizing the system's efficiency, velocity, and precision across varying degrees of maze complexity. Noteworthy is the transparent acknowledgment of certain inherent limitations, thereby fostering a comprehensive understanding of the contextual boundaries within which the robotic system operates.

A. Hardware Setup

The hardware setup consists of an Arduino Uno microcontroller, L293D motor shield, and three ultrasonic sensors HC-SR04. The Arduino Uno serves as the central control unit, while the motor shield provides motor control capabilities. The ultrasonic sensors are strategically positioned on the vehicle to the front, left, and right sides and programmed to detect the distance of obstacles or walls from the body of the vehicle.

B. Motor Control

L293D is a dedicated module that can be fit to Arduino UNO, and Arduino MEGA respectively. The motor shield is connected to the Arduino Uno, enabling precise control of the vehicle's movement. By utilizing the motor shield's capabilities, we can adjust the motor speed and direction accordingly with the help of programming the Arduino IDE and using the Adafruit Motor shield library which has inbuild functions to control motor direction and speed. The L293D is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V.

C. Ultrasonic Sensors

Three HC-SR04 ultrasonic sensors are employed to detect the presence of walls in the maze by detecting their distances. These sensors are connected to the Arduino Uno and provide real-time distance measurements in all three directions namely the front, left, and right sides.

D. Wall-Following Algorithm

Our primary methodology centers around the Wall-Following Algorithm, a crucial element guiding the decision-making process of our maze-solving robot. This algorithm utilizes ultrasonic sensor readings to carefully determine the best path for the robot to take. It's structured with a set of conditions, each playing a specific role in steering the robot through the maze.

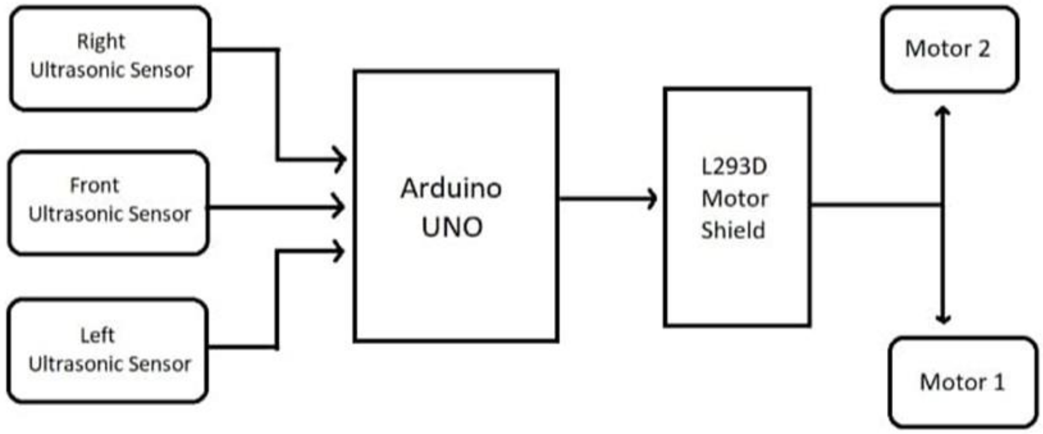

Fig. 1. Robotic overall module structure

At its core, the algorithm dictates that if the left side is clear, the robot should make a left turn without considering inputs from the front or right sensors. This consistent leftward strategy forms a foundational aspect of our maze-solving approach.

The algorithm's next priority comes into play when both the front and right sensors detect open paths, while the left side is blocked. In this case, the robot moves forward with a calculated path. This dual-tiered decision-making process adds adaptability, allowing the robot to navigate through mazes with different layouts.

Here's a simplified representation of the algorithm:

IF THERE IS WAY IN :			Actions
Front	Left	Right	
✓	X	X	Go straight
X	✓	X	Turn left
X	X	✓	Turn right
X	✓	✓	Turn left
✓	X	✓	Go straight
✓	✓	X	Turn left
✓	✓	✓	Turn left
X	X	X	Stop

Fig. 2. Logic Table

The Wall-Following Algorithm guides our robot through the maze by using sensor information to make smart navigation choices. Beyond its use in maze-solving, the algorithm reflects strategies seen in real-world scenarios, where entities, whether autonomous or human-controlled, follow physical barriers for guidance. This strategy is applied in various applications, from autonomous vacuum cleaners to complex warehouse automation systems, where finding the most efficient path is crucial. The algorithm's simplicity and adaptability make it a valuable asset in the realm of maze-solving robotics and broader autonomous navigation scenarios.

E. Maze Environment

In order to systematically assess the efficacy of our robotic vehicle system, we meticulously engineered a bespoke maze environment. This maze was meticulously crafted with precise dimensions, layouts, and features strategically incorporated to rigorously test and challenge the vehicle's navigational capabilities, particularly in the application of the wall-following algorithm. The wall width was made approximately 28cm. The intricacies of the maze design were purposefully tailored to examine the adaptive and problem-solving capacities of the vehicle as it maneuvered through the maze.

The maze, conceived as a controlled experimental setting, features carefully delineated pathways, turns, and obstacles to emulate real-world challenges. Its design encompasses a deliberate interplay of complexities to assess the system's resilience and responsiveness across varied scenarios. The dimensions and contours of the maze were curated with a discerning eye to ensure a comprehensive evaluation of the vehicle's capacity to navigate in diverse spatial configurations.

Figure (3) serves as a visual representation of the maze pattern employed for testing the vehicle. This graphical depiction encapsulates the intricate design considerations, offering a snapshot of the challenges posed to the robotic vehicle during the evaluation process. The maze pattern is characterized by an intentional interplay of corridors, junctions, and enclosed spaces, strategically conceived to gauge the vehicle's adaptability and efficiency in negotiating labyrinthine structures.

It is imperative to underscore that this maze environment serves as a purposeful microcosm, meticulously designed to scrutinize the vehicle's performance under controlled conditions. The deliberate calibration of maze features aligns with our objective to derive nuanced insights into the system's navigational acumen and problem-solving prowess, particularly when subjected to the challenges inherent in maze traversal.

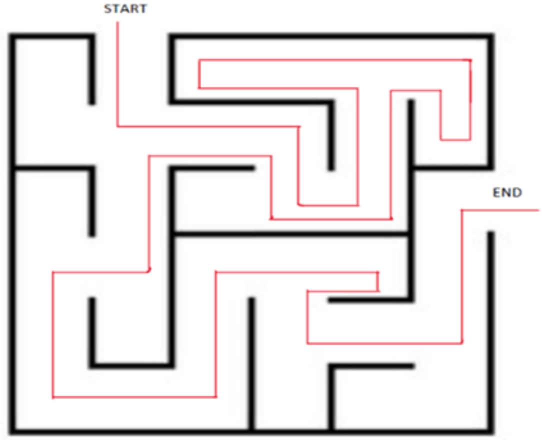

Fig. 3. Maze solved by left wall follower

F. Calibration and Testing

Prior to embarking on the maze experiments, a comprehensive calibration process was meticulously undertaken to ensure the precision of sensor readings and the dependable performance of our vehicle system. This calibration initiative encompassed fine-tuning sensor thresholds and validating the optimal functioning of the ultrasonic sensors.

Given that the L293D motor shield fully occupied the pins of the Arduino UNO board, a strategic adaptation was implemented. The analog pins of the Arduino UNO, conveniently accessible through the shield, were repurposed as digital pins for connecting the ultrasonic sensors to the UNO board. This resourceful utilization of available pins enabled seamless integration of the sensors into the system architecture.

In the calibration process, thresholds for sensor responsiveness were carefully established to align with the specific characteristics of the maze environment. After rigorous experimentation, the ideal sensor thresholds were determined to be 8cm for both the left and right sensors, with the front sensor calibrated to a threshold of 15cm. These thresholds were meticulously selected to optimize the vehicle's responsiveness to maze features, striking a balance between sensitivity and robust obstacle detection.

Furthermore, the maze dimensions played a pivotal role in shaping the calibration parameters. The width of the walls within the maze was measured to be approximately 28cm, a crucial metric influencing the vehicle's proximity thresholds and decision-making capabilities as it adhered to the wall-following algorithm.

Subsequent to the calibration procedures, a series of methodically orchestrated tests were conducted to validate the performance of the wall-following algorithm. The vehicle was strategically placed within the maze, and its movements were closely monitored as it traversed the labyrinth, consistently following the walls. The assessment focused on evaluating the vehicle's adeptness in successfully navigating the maze and making informed decisions in accordance with the wall-following algorithm.

In essence, the calibration and testing phase served as a pivotal precursor to the experimental trials, ensuring that the vehicle system was primed for optimal performance within the intricacies of the designed maze environment. The integration of precise sensor thresholds, coupled with considerations of maze dimensions, attests to the meticulousness of our approach in validating the reliability and effectiveness of our robotic system.

G. Scenarios and Decision Making

We considered various scenarios during testing, including dead ends, multiple paths, and intersections. The wall-following algorithm dynamically adjusted the vehicle's direction based on the sensor readings and determined the optimal path to follow in each scenario.

H. Performance Metrics

To evaluate the effectiveness of our methodology, we employed several performance metrics. These included completion time, which measured the time taken by the vehicle to solve the maze, as well as the accuracy of following the designated maze path. We also tracked the number of collisions with walls to assess the robustness of the algorithm.

I. Limitations and Future Work

While our methodology demonstrates promising results, it is important to acknowledge its limitations. The performance of the wall-following algorithm may be influenced by factors such as sensor accuracy, environmental conditions, and maze complexity. Future work could focus on improving the algorithm's adaptability to different maze structures and integrating additional features such as developing the code and making it more advanced for enhanced obstacle detection and avoiding or reducing the collisions with the walls and solving different types of maze patterns.

III. FLOWCHART

Below is the flowchart of the system:

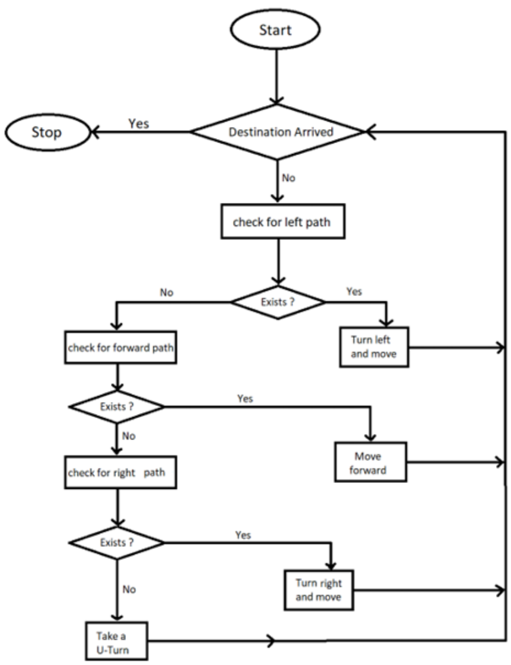

Fig. 4. Flowchart illustrating how the robot operates

IV. RESULTS AND DISCUSSIONS

In conclusion, the conducted experiments and calibration processes substantiate the triumphant implementation of the wall-following algorithm within our intelligent robot designed for maze-solving. The meticulous calibration of sensor thresholds, taking into account maze dimensions, paved the way for precise navigation and informed decision-making by the vehicle system. Through rigorous testing in a deliberately designed maze environment, the robot consistently demonstrated its capacity to adeptly follow walls and navigate through complex spatial configurations.

The results underscore the viability and efficacy of the Micro-mouse inspired concept, positioning it as a promising approach in the realm of autonomous robotics. The successful execution of the wall-following algorithm not only validates its practical application in maze-solving scenarios but also contributes valuable insights for future advancements in autonomous robotic systems. The integration of analog pins for sensor connectivity, calibration of optimal sensor thresholds, and strategic adaptation to maze dimensions collectively showcase a methodical and adaptable approach to autonomous navigation.

These findings extend the discourse on intelligent robotic systems and autonomous maze-solving, providing a foundation for further research and development in the field. The successful application of the wall-following algorithm exemplifies its potential significance in addressing real-world challenges where autonomous navigation is a critical requirement. As autonomous robotics continues to evolve, the outcomes of this study contribute to the growing body of knowledge, fostering innovation and advancements in the quest for intelligent and adaptive robotic systems.

VI. CONCLUSION

This intelligent robot based on the concept of a micro mouse successfully finds a path in the maze and completes the expected result. Multiple ultrasonic sensors are used so that the robot can acquire information about the environment accurately. By following the prescribed actions based on the sensor inputs, the vehicle is able to navigate the maze efficiently. The methodology provides a structured approach to solving mazes. It can be further extended and optimized for more complex scenarios.

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