Autonomous Micromouse Vehicle for Efficient Maze Mapping and Navigation in Competitive Environments

Abby Mathieu, Christina Karagianis, Jason Xue
Advisors: Dr. Se Young Yoon and Dr. MD Shaad Mahmud
Electrical and Computer Engineering, University of New Hampshire, Durham, NH 03824
Contact Information

Introduction

Autonomous navigation is a crucial challenge in robotics, requiring efficient algorithms and sensor integration to enable vehicles to explore and traverse unknown environments. The Micromouse competition challenges participants to develop autonomous robotic vehicles capable of efficiently navigating a maze.

The primary goal of this project is to design and develop a small-scale autonomous vehicle that will first search and map a maze and then solve the maze in the shortest amount of time possible.

Research Question

Can we create a cost-effective autonomous robot that can map and solve a maze? The aim of this project is for the robot to be a starting point for a potential IEEE Micromouse competition team at the University of New Hampshire.

Methodology

STM32 Nucleo Microcontroller

Sensing System

- **Infrared Sensors (HiLetgo):** Short Range Wall Detection
- **Inertial Measurement Unit (LSM6DSOX):** Maintaining Stability and Adjusting Turning Position

Proportional-Integral-Derivative (PID) Control

- **Closed-Loop System:** Incorporated encoder feedback to continuously adjust motor input.
- **Motor Control:** Utilized brushed DC motors with an H-bridge (L298N) powered directly by the battery.

Search Algorithm

- **Flood-Fill Algorithm:** Assigned incremental values to cells starting from the goal to determine optimal paths.
- **Dead-End Avoidance:** Used a Stack to track and prevent revisiting non-optimal paths.

Total Cost of System: $90.46

Micromouse and Maze

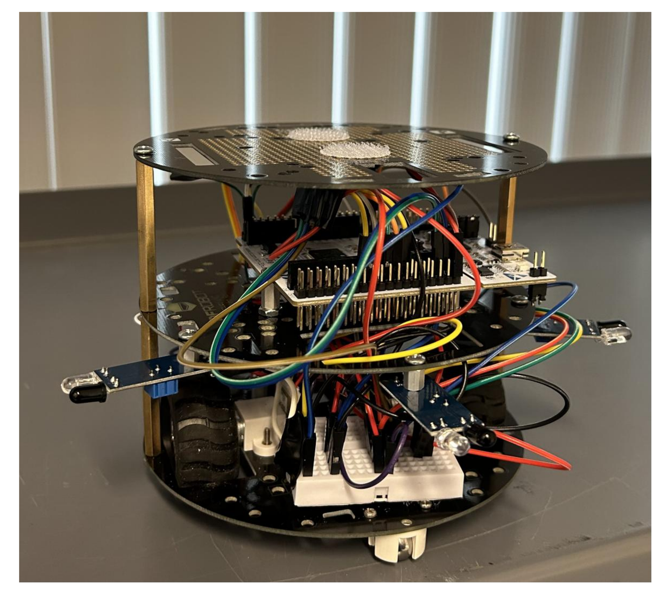

Figure #1 Micromouse Robot

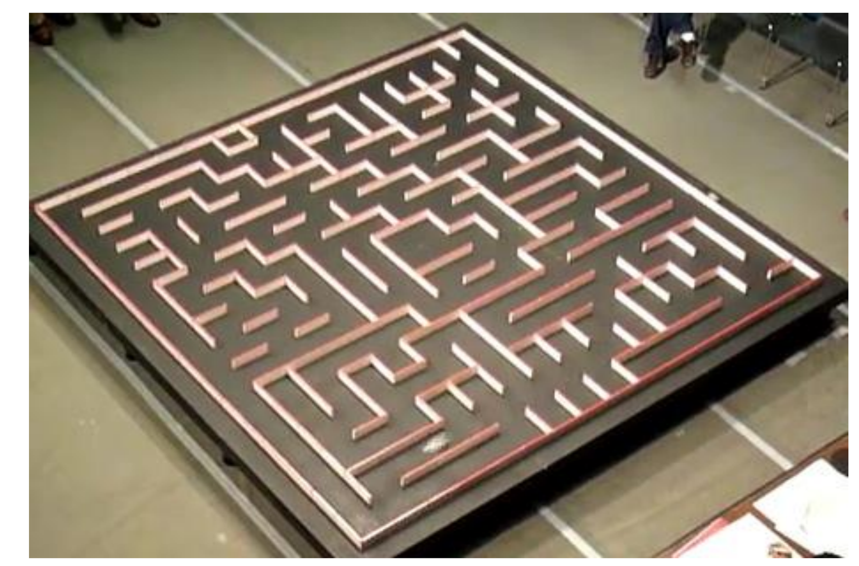

Figure #2 Standard Size Maze for the Micromouse competition [8]

Block Diagram and Testing Procedure

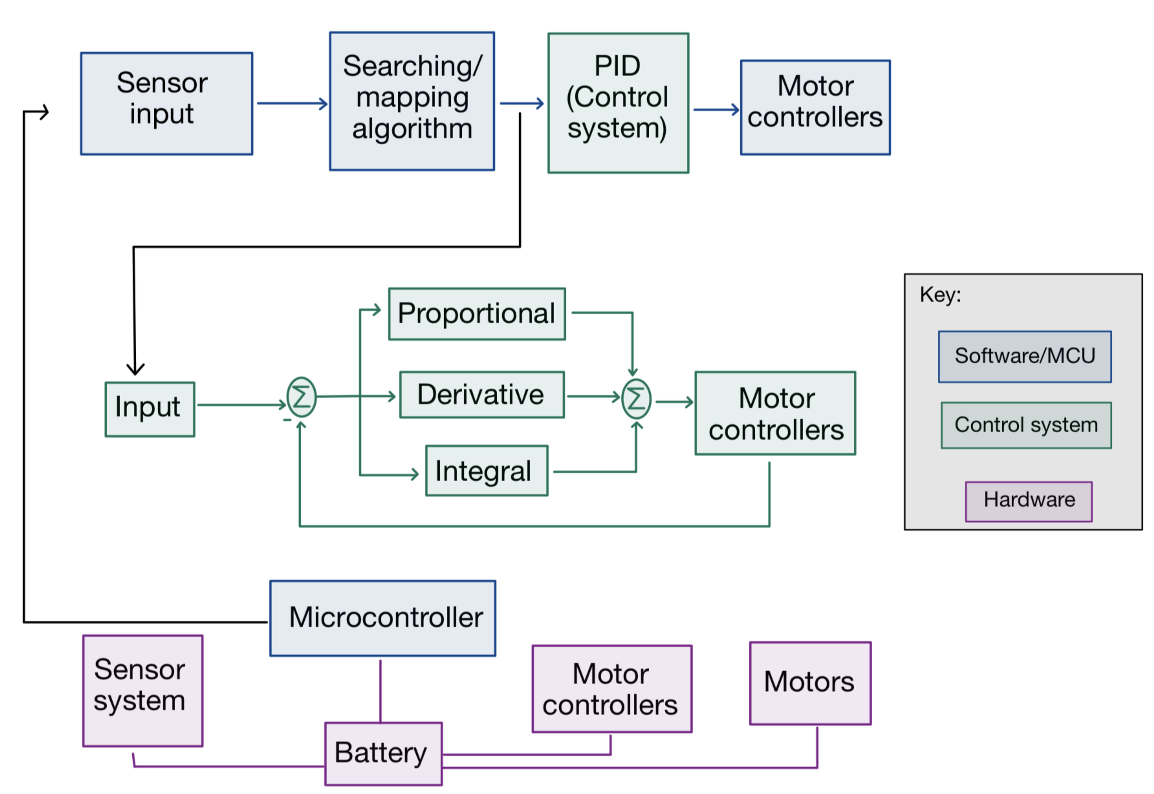

Figure #3 Overview of the Micromouse System

- Tested vehicle's ability to travel in a straight path and make 90-degree turn using only the Inertial Measurment Unit
- Tuned Control System
- Implemented Pathfinding Algorithm in simulated environment

- Implemented Infrared Sensors of Vehicle – these were tested by having the vehicle travel between a set of walls

- Floodfill Algorithm will be applied to the system as the final step to ensure that it works as intended with the other subsystems

Figure #4 Testing Procedure for the Project

Algorithm Results

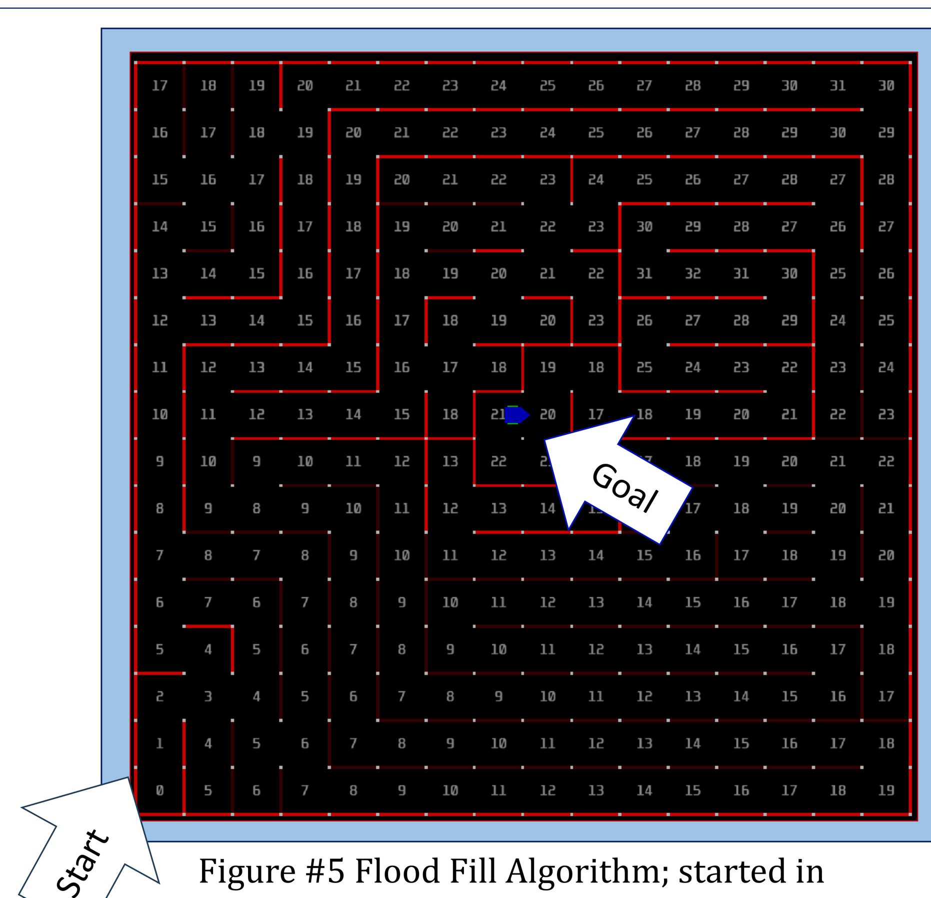

Figure #5 Flood Fill Algorithm; started in bottom left corner and navigated its way to the center where the blue dot is

Sensor and Control Systems Results

- Gyroscope outputs correct angles necessary for turning and keeping a straight path

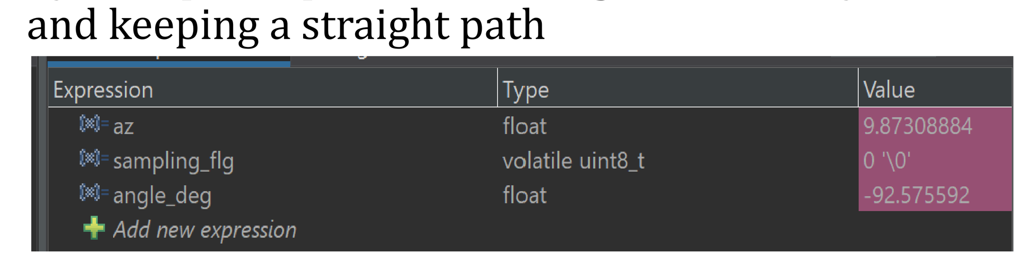

Figure #6 Result from testing Gyroscope in STM32CubeIDE

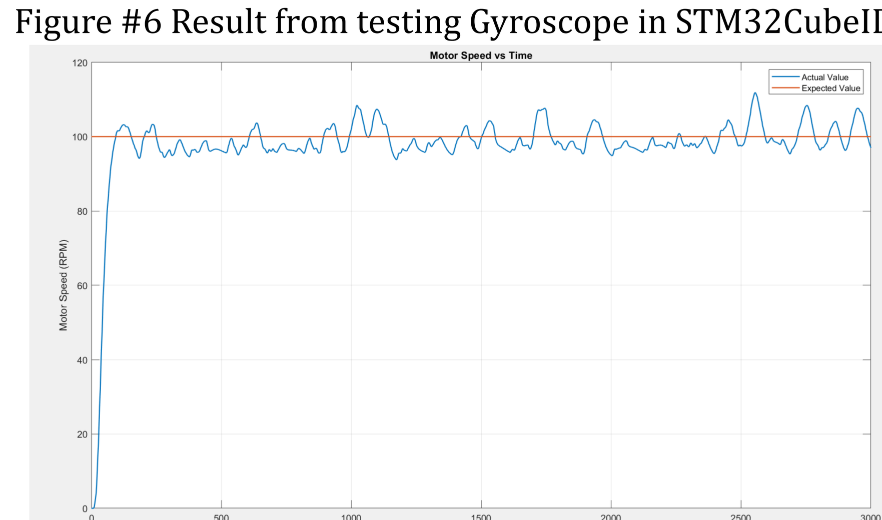

Figure #7 Step Response of the PID Control

Challenges

- **Sensor Integration and Accuracy:** The controls system relies on accurate sensor data to efficiently navigate the maze. Any faults in this data can lead to problems in navigating the maze.
- **Algorithm Optimization:** Making sure that the selected algorithm can efficiently map and solve the maze with the hardware selected.
- **Gyroscope Drift:** Over long distances drift can build up and affect the robot's ability to move straight
- **Wire Management:** There are many different sensors and parts, so the wires must be organized to not disrupt the balance of the vehicle

Future Work

- Optimize algorithm to simplify code while maintaining accuracy of pathfinding
- Simulate competition environments with allotted time for maze mapping and maze solving
- Implement more sensors into the robot such as Ultrasonic Sensors for more accurate wall detection abilities
- Design PCB which can incorporate all the sensors and the microcontroller onto one board
- Establish a Micromouse Team competition team at UNH

Conclusion

This Micromouse project focuses on developing an efficient maze-solving system using the Floodfill algorithm for instant pathfinding, a well-tuned control system for precise maneuvers, and optimized sensor configurations. The goal is to create a cost-effective design that enhances autonomous navigation performance.

Acknowledgements

Thank you to our advisors Dr. Se Young Yoon and Dr. MD Shaad Mahmud for their continued support throughout this project. We would also like to extend a heartfelt thanks to our family and friends for their unwavering encouragement and support.

References

[1] S. Dong, Y. Zhou, H. Wang, and H. Chen, "A path planning algorithm based on modified genetic algorithm for micromouse," *2011 6th International Conference on Computer Science & Education (ICCSE)*, Singapore, 2011, pp. 1253-1256, doi: 10.1109/ICCSE.2011.5971240.
ouse Guide for Beginners, [Online]. Available: https://micromouseguideforbeginners.wordpress.com/2-a-checklist-of-parts-you-will-need/. [Accessed: 16-Oct-2024].
[2] M. Li, Z. Li, and Q. Hu, "A flood-fill algorithm for micromouse with path length estimator," *2020 IEEE 5th Information Technology and Mechatronics Engineering Conference (ITOEC)*, Chongqing, China, 2020, pp. 391-394, doi: 10.1109/ITOEC49072.2020.9096193.
[3] T. Alhmiedat, "Autonomous Maze Solving Robotics: Algorithms and Systems," *ResearchGate*,[Online].Available: https://www.researchgate.net/publication/355170025_Autonomous_Maze_Solving_Robotics_Algorithms_and_Systems. [Accessed: 16-Oct-2024].
[4] A. Mishra and M. R. Tripathy, "Efficient Maze Solving Algorithm for MicroMouse Using Hybrid of Flood Fill and Dijkstra Algorithm," *2023 8th International Conference on Communication and Electronics Systems (ICCES)*, Coimbatore, India, 2023, pp. 1311-1315, doi: 10.1109/ICCES59002.2023.10253498.
[5] L. Bo, X. Shi, Z. Yan, and X. Zhang, "Design and Implementation of Micromouse Maze Solving Algorithm Based on FloodFill," *2018 37th Chinese Control Conference (CCC)*, Wuhan, China, 2018, pp. 7236-7240, doi: 10.23919/ChiCC.2018.8599230.
[6] M. Tanase and P. Svasta, "Micromouse – A case study for mechatronics design education," *2014 9th International Symposium on Advanced Topics in Electrical Engineering (ATEE)*, Bucharest, Romania, 2014, pp. 1-4, doi: 10.1109/ATEE.2014.6957327.
[7] M. Tanase and P. Svasta, "Micromouse – A case study for mechatronics design education," *2014 9th International Symposium on Advanced Topics in Electrical Engineering (ATEE)*, Bucharest, Romania, 2014, pp. 1-4, doi: 10.1109/ATEE.2014.6957327.
[8] Woftech, "Micromouse Robot," *Woftechact*, Sep. 2014. [Online]. Available: https://woftechact.wordpress.com/wp-content/uploads/2014/09/micromouse-robot.jpg. [Accessed: 22-Oct-2024].
[9] M. Tran, "Micromouse V2," *Matthew Tran*, 2020. [Online]. Available: https://matthewtran.dev/assets/img/2020/mmv2_15.jpg. [Accessed: 22-Oct-2024].