EEE3099S Milestone 2

Micromouse

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Chapter 1

Introduction

This report is an overview of the development process of a maze solving robotic mouse. Specifically this report is concerned with the first steps taken with interfacing with the robot. It is not an overview of the project as a whole but rather the first steps in a larger process.

1.1 Requirements

A set of requirements for the mouse were given and are as follows.

1. Calibration
2. Initialisation Routines
3. Identify and Hold a Line
4. Surrounding Awareness

1.2 Sensor Integration

The robots awareness of the surrounding world is completely reliant on the use of infrared sensors. These sensor are made up of an emitter and receiver, the emitter sends out infrared light while the receiver receives infrared light and transforms it into a voltage. This voltage is then read by the robots ADC, from which point appropriate actions can be made.

The robot has two different sensing goals. One is to sense a line grid which tracks out the maze and the other is to detect the walls of the maze. In the case of the line the infrared reflections are at a minimum when a sensor is directly over the line, this is due to the lines black colour and consequentially low reflective properties. For the walls, the closer a wall is to a sensor the more reflections the receiver detects. Thus a high voltage would indicate a wall.

1.3 Achievement Matrix

Requirement	Fulfilled (1, 0)
Calibration	1
Initialisation Routine	0
Identify and Hold a Line	1
Surrounding Awareness	1

Table 1.1: Achievement Matrix

Chapter 2

Design

2.1 Sensor Design

In practice the infrared light picked up the by the receiver is made up of more than just the light emitted by the emitters. Surrounding light sources can be a big influence on readings obtained.

The lighting in any testing environment will always be slightly different, changing due to time of day and different weather. As well as ambient light, infrared light from adjacent emitters can leak over to other sensors, also introducing noise and uncertainty.

These ambient light values can cause problems for the sensing component modules of the micro-mouse. As the lighting changes, so do the readings of the infrared sensors on the micro-mouse. These fluctuating values make setting fixed threshold values for your sensors impractical.

In order to solve both these issues an emitter pattern was developed. First all emitters are turned off and the readings are taken, these provide an ambient light level. Then each emitter is turned on one by one and its corresponding receiver reading is taken. After which the difference between the ON value and OFF value is taken.

$$Sensor_{Difference} = Sensor_{ON} - Sensor_{OFF}$$

This process ensures that readings taken only look at the reflections of infrared light, and other influencing factors are removed.

In the graph on the right, the emitter values are shown vs time. It can be seen how there is a repetitive pattern of turning each emitter on and off. Sensor readings are taken at times corresponding to their emitter being on.

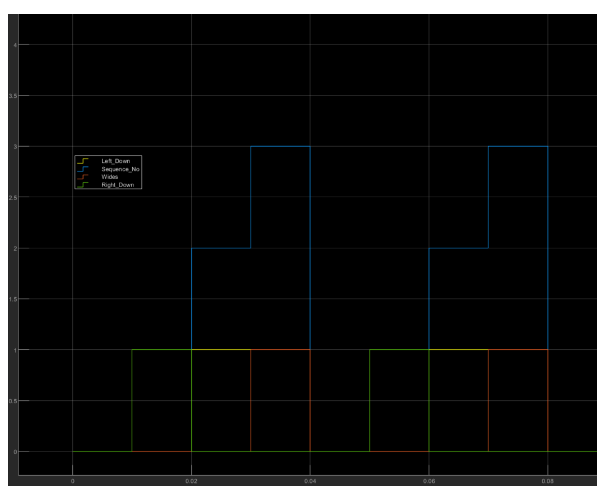

Figure 2.1: Sequence Graph

2.2 Line Tracking

The two central downward facing sensors were used to detect the black line. Each sensor reading would decrease in response to it moving closer to the line, with the reading being at a minimum when the sensor is directly over the line. This is due to the reduced reflections of the black line.

The goal of the robot is to keep both sensors on either side of the line, thus keeping the robot centered on the line. An error representing the robots offset from the line needs to be derived from the sensors readings, this error value can then be fed through a controller to the motors, at which point the motors will work to minimise this error.

The error value can be calculated by subtracting each sensor reading from each other.

$Error = Sensor_{DownLeft} - Sensor_{DownRight}$

When the robot is centred on the line each sensor receives the same amount of reflections, resulting in an error of 0. As the robot moves off center one sensor moves towards the line while the other moves away from the line, this results in readings from one sensor decreasing and readings from the other increasing. Thus the error grows either positively or negatively depending on the direction of the offset.

The figure on the right shows an ideal approximation of the left (Red Line) and right (Purple Line) sensor readings as well as the error (Blue Line) vs the robots offset. This figure shows how the sensor readings decrease when the robots line offset grows in either direction and how this results in either a positive or negative error.

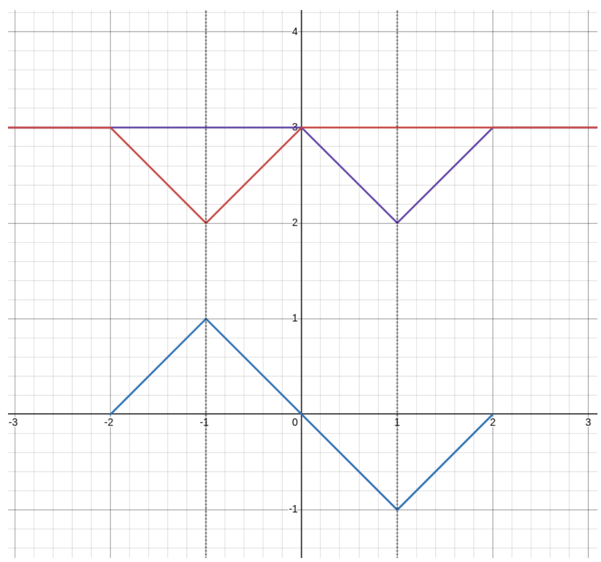

Figure 2.2: Error vs. Position

This error is then fed through a simple proportional controller which scales the error by an appropriate amount. Once scaled the error is fed into the motors. A set speed is also given to both wheels. The speed for each wheel can then be calculated as follows.

$LeftWheel = SetSpeed - K * error$

$RightWheel = SetSpeed + K * error$

This causes the robot to turn left in response to a positive error and right to a negative error. This allows the motors to move to correct the robots offset.

This process is repeated continuously as the robot travels along the line.

2.3 Cross-Over Detection

The maze the micro-mouse must solve is structured in a grid pattern with lines running vertically and horizontally. This results in the forming of intersections. These intersections can be immensely useful for accurately navigating the maze.

The robot is functionally operating in line following mode by default. During the line following process the micro-mouse is also sensing for crossroads. This is done in a similar way to line following

The distance between the two line following sensors made it challenging to accurately detect the presence of a crossroad.

On the micro-mouse are two IR LED's dedicated to wheel encoding on the farthest left and right sides of the board. These sensors are capable of being bent to face downward to the lines below. This provides two additional sensors solely for the purpose of crossroad detection.

This allows for crossroad detection to be handled using a similar methodology to line following. As the robot approaches and traverses over a crossroad the value will drop below the threshold due to the presence of the black strip underneath the sensors. This results in the crossroad function to run.

The crossroad function stops the motors for a set period of time in which time Wall detection occurs. A small debouncing process occurs when the robot returns to line following mode. This prevents the mouse from immediately detecting the same crossroad and becoming stuck in an endless loop.

2.4 Wall Detection

The closer or farther a wall is determines the strength of reflection detected by the LED's. A threshold value was appropriately set insuring the micro-mouse did not detect a wall that is not directly next to or in front of it.

During the period of time where the micro-mouse is at a crossroad, the micro-mouse will use the:forward , left and right facing sensors to detect whether or not a wall is present. If a wall is detected the respective: centre, left or right LED will flash indicating that the robot has sensed a wall.

Chapter 3

Debugging

3.1 Line Following

Upon debugging of the downwards facing IR sensors, it was evident that one sensor produced a much higher voltage then the other, even when both received the same amount of IR reflections. In order to account for this a gain term was introduced for each sensor, this allowed each sensor to be tuned to have similar readings at similar levels of reflections.

Tuning of the proportional control system was needed. At high gains the robot was very twitchy and would occasionally become unstable and veer off course. At low gains the robot would be much smoother, but would take far longer to correct it's course. A nice middle ground was found, the robot would respond relatively quickly but did not overshoot and become unstable.

3.2 Crossroad Detection

Crossroad detection is essential for the proficient operation of the micro-mouse. During initial testing the consistency of crossroad detection was a concern. Finding a threshold value where the sensors could accurately detect a crossroad was challenging and inefficient.

Wheel encoding was never a function that was considered. The wide IR LED's were therefore repurposed by bending them down to face the track. This allowed for them to be used for crossroad detection instead.

Their distance away from the line used in line following made them far more accurate and realisable for crossroad detection. Using the same processes as line following meant that their successful operation was realised almost immediately.

3.3 Wall Detection

During testing for the wall detection function it was discovered that while the forward facing IR LED's were functioning as intended. The left and right facing wall sensors were not.

The voltage differential between there being a wall directly in front of the sensor and no wall at all was almost zero. This made wall detection impossible.

To correct this problem two things were done. First the higher power connection to the IR emitters was soldered. This provides the emitters with a greatly power source resulting in a better emission capacity.

Secondly, electrical tape was wound around the IR receivers. By wrapping them in electrical tape it greatly reduced the amount of ambient light entering the sensors and improved the overall differential making wall detection more efficient.

Chapter 4

Results and Analysis

4.1 Line Following Improvements

While the current line following controller is adequate, there is definitely room for improvement. A derivative term will be added to the controller. This term takes into account the rate of change of the error and feeds this into the motors. The derivative term would allow for higher gain values without the system becoming unstable. Doing this will allow for smoother line following and higher speeds.

4.2 Wall Detection

Currently there is no initialisation routine performed for wall detection. While the sensors ability to detect the wall has been improved through the physical upgrades to the board the potential, for mistakes is not negligible. Without any kind initialisation the ambient lighting and difference in wall texture can have an impact on the sensors reliability. This initialisation technique may scan the surroundings and use readings obtained as a benchmark for set thresholds. This approach to setting thresholds would result in a far more robust wall detection algorithm.

4.3 Next Steps

At the present stage the robot is able to sense and localise itself in accordance to its surroundings, but it is unable to make decisions based upon this data. The next steps in development is to provide the robot the ability to make decisions based upon this localisation data. Once achieved this would allow for the robot to transverse the maze.

4.4 Github Link

Click Here for Github