LINE FOLLOWER ROBOT

Robotic Application Development

Higher Diploma in Software Engineering

Project Report

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Abstract

In this project we are addressing the task given for the coursework of the Robotics Application Development project. This project covers the use of PID controllers, Robotic components and Microcontroller programming, spiced up with Creative designing. The methodology of this project is to identify the given task, requirement analysis, design and implementation. The project was done from an experimental standpoint by going through trial and error. Ultrasonic sensors, IR sensors (Infrared) and Motor Drivers were tested for the development of this project. We wanted to implement a way to calculate and make decisions according to the inertia and the angular velocity of the robot. Therefore, we continued experimenting further with Inertial Measurement Units (IMU). The purpose of writing this documentation is to describe all about the robot, that is how to analyse robotic problems, the efficiency of the robot, the elements of interest, structure and implementation process of the robotic design.

Acknowledgement

First, we would like to express our sincere gratitude to respectable mentor, Mr. Vimukthi Pathirana for guiding us and giving us your continuous support and presence whenever needed. Also this project cannot be completed without the effort and cooperation from our group members.

In addition, we wish to express gratitude to our families,classmates and friends for their ongoing support, guidance, and excitement.

Table of Contents

Chapter 1: Introduction

1.1 Scope and the Introduction to the Robot

The designed robot is a line follower which follows a certain path while avoiding obstacles in its pathway by processing feedback from external sensor mechanisms. This application was implemented with Arduino Platform infused with Micro C language. This remains as the scope of our project.

A black line is drawn on a white area and it is detected and followed by this robotic application. This application is entirely reliant on sensors. For path detection, we are using multiple sensors and sensor types which are supported by the Arduino platform and namely, Infrared and ultrasonic sensors are used. Furthermore we planned on using PID (proportional integral derivative) controllers implemented in the code to increase accuracy and the stability of the robot.

1.2 Used components and equipments

1.2.1 Arduino Uno

This development platform was used to store the instructions in an ATmega328P microcontroller and give functionality to the robot. Both digital and analog pins are used and it is powered with an external battery in this application

1.2.2 IR Sensors

Two IR Sensors were used to sense the brightness of the Infrared light (IR Light) which is bounced back from the surface. This can be utilized to detect where the robot is moving in a given black line by looking into the reflected IR rays detected.

1.2.3 DC motors with gears

Two ordinary DC motors were used to drive our robot. Helps in controlling mobility.

1.2.4 Toy wheels

Self explanatory pair of toy wheels, used to give physical mobility to the robot.

1.2.5 Jumper wires

Female to male, male to male and female to female jumper cables were used for the connectivity of the modules of the robot.

1.2.6 MPU6050 IMU sensor

The gyro sensor and the accelerometer of the MPU6050 is used to derive the angle the module is on. Furthermore the angular velocity and the inertia is also used. (Discussed in the 3.2 Limitations and Further Improvements)

1.2.7 HC-SR04 ultrasonic sensor

We used this sensor in our robot to detect the distance to an object using a sonar.

1.2.8 L298 motor driver

In order to control both speed and spinning direction of DC motors, as this is one of the easiest ways to do the operation.

1.2.8 Lead Solder

Used to connect 2 wires or circuit connections and form strong joints with other metals.

1.2.9 Soldering iron

This hand tool is used to heat solder,which allows the solder to flow between the components that need to be joined.

1.2.10 Cable tie

We used cable ties to bind the cables and wires together because they provide high binding strength and helped us keep the wires organized properly.

1.2.11 Caster wheel

Attached to the bottom of the body of the robot to enable it to be moved.

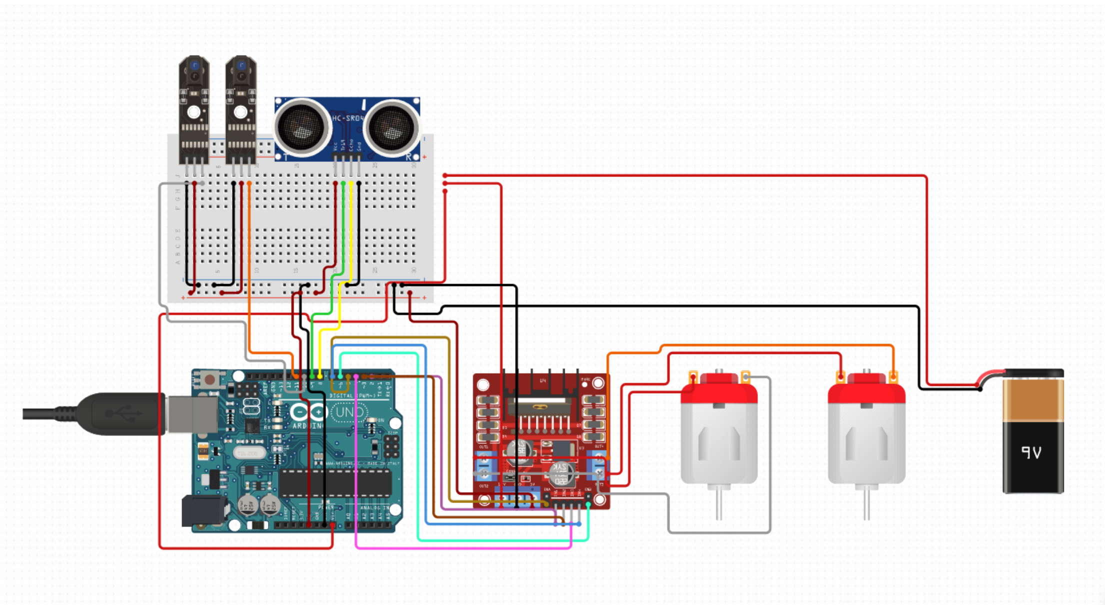
1.2.12 Black tape

The black tape is used to make the route for the line follower, with a black line on a white surface to detect the black line.

Chapter 2: Design & Implementation

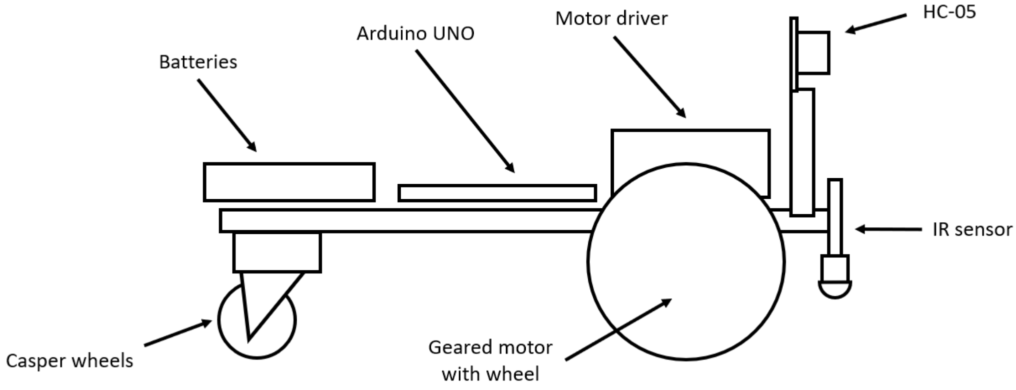
2.1 The Design

The design of the robot is fairly simple. As in the scope of the project, it is required to detect nearby objects and the black pathway line. For this task we specifically need an HC-SR04 sensor and two IR sensors. The whole design of the robot mainly depends on these components and the two sets of motored wheels. Our first circuit schematic design draft of the project is as follows.



Our initial idea was to power the necessary components such as the motor driver, ultrasonic sensor and the IR sensors – with the 9v battery while using another source to power the Arduino Uno.

The robots' overall component placement and the design idea was basic. The following schematic does not indicate the wiring but the cable management and neatness was concerned while designing the robot. For instance, the motor driver has been moved to the front as it would be nearer to the motors.



2.2 Implementation

We planned the robot to be built with homemade material for the most components instead of purchasing products from the markets. Our big idea is to use plywood and follow tricks to improve the stability of the structure of the robot.

Apart from the technical product design for the minimal viable product, we wanted to implement creative ideas into the robot. For example, the sound emitters of the ultrasonic sensor can be creatively looked upon as eyes of a character.

2.2.1 The base

As stated above the base of the robot is made using plywood. We settled on using '3-ply' plywood, it is a slightly thicker and more robust 3 layer plywood that will provide us with enough structural integrity and stability when used as the base. By using hacksaws and drill equipment we engineered the plywood board into the base for our robot.

2.2.2 The robot

The robot was built with simplicity in mind. The plywood base enabled us to create a hefty feeling robot with a good weight to it. The weight gives the robot better traction, allowing for more accurate and consistent manoeuvring.

The robot's motor driven wheels are placed on the sides of the front of the robot behind its two main sensors. To allow the robot to rotate, a caster wheel is attached to the centre of the robot's rear end. (The wheel placement is triangular, with the main two wheels at the front and the caster wheel at the back centre.)

To better accommodate the placement of the electronics, we placed them closest to where their wiring has to go, this way, the wiring is much more organised. The motor driver is placed at the front end of the base, between the two motors and wheels. The Arduino UNO is placed at the centre of the base. The battery pack is placed at the back of the base and right above where the caster wheel is, directing its weight to the caster wheel to increase the traction at the back end.

At the front most end of the robot and in the centre, two mounts or brackets will extend vertically, one extending upwards, and one extending downwards. The bracket extending upward is for mounting the HC-SR04 ultrasonic sensor and the bracket extending downwards is to mount the IR sensor.

2.2.3 Appearance

We did in fact take into consideration the appearance of our robot. It is modelled to look like a cute animal. The HC-SR04 sensor is its pair of eyes and it has a set of three wheels for legs. It really looks a lot like the *WALL-E* robot except that it's a little flat.

Chapter 3: Testing

3.1 Troubleshooting and Assumptions

1. Economical Issues

   We have faced economic issues while trying to buy equipment for our project. All the equipment prices have been increased due to the current situation of the country. We were unable to buy some equipment because of the price being out of our budget and so we purchased equipment that was priced significantly lower.

   Solution: We discussed with our team members and came up with a great solution to find equipment without spending a lot of money. Therefore we agreed to bring missing equipment from our home if it was available. As a result, we were able to find an Arduino UNO board to develop our platform. (Arduino UNO boards are priced very high).

2. How to decide the structure of the robot

   There was a problem with the structure of the robot because although the structure had the completeness of the robot we envisioned, there was an issue with how well it balanced. Therefore we needed to recreate the completed structure while focusing on making sure it balanced properly. This proved to be slightly challenging for our team but we managed to find a solution.

   Solution: We improved the structure of our robot by reducing its height and length (this increased its surface area). The robot then looked a lot flatter and had a much lower centre of mass. The new robot structure did not have any balance issues and so we finalised it as our structure.

Chapter 3: Conclusion

3.1 Implementation

Our line following robot was built to follow a prepositioned path while avoiding obstacles in its pathway by using its external sensor's data. The robot's application written in Micro C language will enable the robot to use all of its external sensors in unison to detect the path and make the robot traverse it with minimal error.

The Robot's primary sensor used for the detection of the black line are two Infrared sensors, the sensors can be used to differentiate black from other colours. For detection of obstructions in the robot's path a single ultrasonic sensor will be used. An additional MPU6050 IMU sensor will be included to use its inertial measurement to improve the robot's stability.

As for the design and schematic, the robot will use basic components to power and drive the two motors using an L298 motor driver and a 9V battery. The three sensors will be powered by the Arduino's 5V output.. The robot's components will be placed on a flat frame fabricated using plywood. The battery, Arduino UNO and motor driver will be mounted flat on top of the frame. Separate mounts for the HC-SR04 and IR sensor will extrude vertically at the front end of the plywood frame (above for the HC-SR04 and below, facing downwards, for the IR sensor). The geared motors will be placed at the front end of the frame connected to the wheels on both sides. A caster wheel will be attached at the back of the frame in the middle to allow the robot to have support on the back end and to be able to make turns during traversal.

3.2 Limitations

A major factor that limited the development and outcome of our project was the present economic constraint. Due to the ongoing economic crisis in Sri Lanka, prices of Arduino gear and parts have soared because of imports being restricted.
Although we were able to purchase the main components for our robot, we were not able to secure a good pre-built frame as they were priced outside of our budget.

To overcome this, we created a frame by using plywood, this however, came with its own disadvantages. We went through many iterations of our design for the plywood frame trying to make it as balanced and structurally sound as possible. The final iteration we settled on works well but it is still preferred that we use a pre-built frame instead as they are built using a lightweight plastic and have better structural integrity.

Another limiting factor was that we could not utilise the MPU6050 IMU sensor as we were unable to fully understand its outputs and how we could implement them into our algorithm's code. The math behind the MPU6050 is very complex. If we were to implement the MPU6050 fully, it would mean having to work around with 6 more variables (gyroscope and accelerometer, 3 variables each), this increases the risk factor of our resulting robot. The most we were able to do is understand what the sensor output data meant but we weren't able to implement it into our code. In hindsight, it would have taken a considerable amount of extra time to fully understand the MPU6050's output and to implement it into our algorithm and so we decided to discard the plan to use the MPU6050 entirely and focus on the line following aspect of our robot.

3.3 Further Improvements

To improve our robot's design and capability, we can implement the MPU6050 IMU sensor. The MPU6050 sensor outputs raw data that must be converted. To convert the raw data into a comprehensible unit like force (g) or degree per second (°/s), the sensor raw data must be taken in 2's complement before it is divided by a sensitivity scale factor. During the development of our robot, a significant amount of time was spent on understanding the outputs of the MPU6050 and the mathematics behind them.

The MPU6050 can be incorporated in a way that the algorithm will use its data to alter the speed of the robot's movement as it traverses the line, sort of like an automatic braking system. The algorithm can be developed to use the sensor's data to control the power going to the wheels when the robot is making a turn. The data from the sensor can also be used to improve the accuracy of our robot's movement as it outputs data like pitch and tilt allowing the algorithm to be aware of the exact orientation of the robot.

The robot has high potential if used in industrial environments, namely, warehouses, harbours, factories or even simpler environments like restaurants or libraries. Because of its autonomous capabilities, it can be designed to carry out tasks like transporting items from one point to another.

3.4 References

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