ENEL 387 Project

A Robot for the “End” of the World

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TABLE OF CONTENTS

Section 1: Design Process **1**
- 1.1 Problem Statement 1
- 1.2 Constraints 1
- 1.3 Research 2
- 1.4 Block Diagram 2
- 1.5 Parts 2
- 1.4 Schematic 3

Section 2: Operation **4**
- 2.1 The Robot 4
- 2.2 The Course 4
- 2.3 How it all works 5
- 2.6 IR Sensor 6

Section 3: Testing **7**
- 3.1 Testing the Motors and Motor Drivers 7
- 3.2 Testing the Obstacle Sensor 8
- 3.3 Testing the IR Sensor 8
- 3.5 Testing the Whole System 9

Section 4: Future Plans **10**
- 4.1 Areas of improvement 10

Section 1: Design Process

1.1 Problem Statement

Imagine a person trying to practice social distancing in case of a global pandemic. They would need a robot that can help them with their needs, right?

Well, this project is almost exactly like that! The object of this project is to create an autonomous robot using the STM32VLDiscovery Board. The robot be put in an approximately 2m by 1m track. The robot must be able to use the navigation lines to move in the track. It must be able to detect if it is in a specific room. Lastly, it must be able to detect the target lines in the room.

1.2 Constraints

Taken from Dave Duguid's project requirement handout:

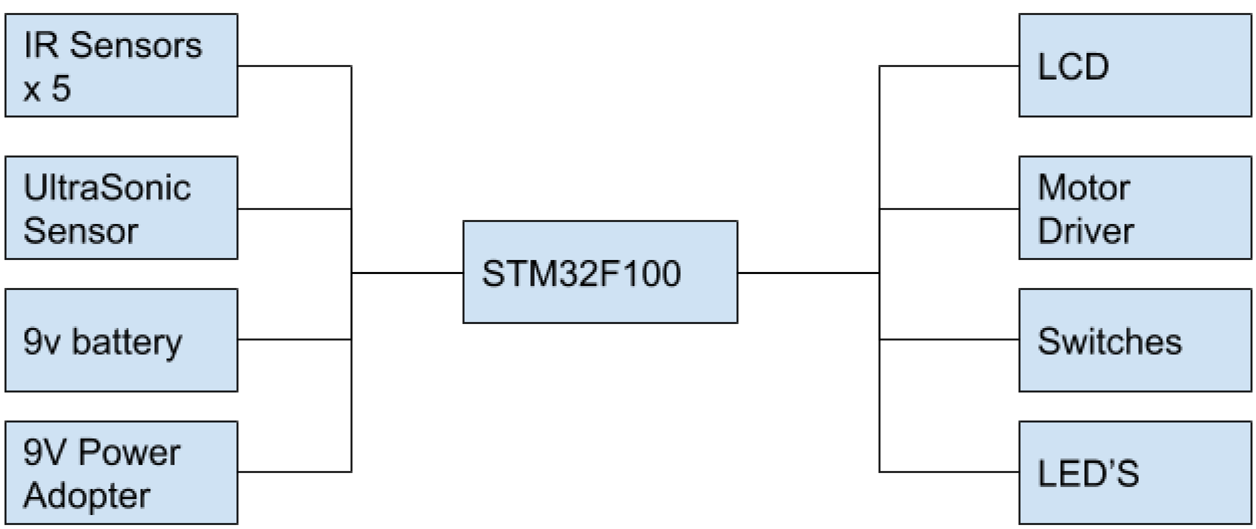
- Must accept dynamic inputs from the outside world.
- Must provide controlled outputs to the outside world.
- Must incorporate at least two sensors in addition to those provided on the ENEL 384 board.
- Must include both digital and analog sensors.
- Must incorporate at least two output devices in addition to those provided on the ENEL 384board.
- Must have at least two different output interface systems (PWM, SPI, UART, GPIO to external devices).
- Must have at least one output device with a current requirement greater than the STM32F100 rated output current.

1.3 Research

We began the project by researching robots just like this. As suggested by Dave, we have watched the Trinity College International Fire Fighting Robot Contest. Also, since the STM32VLDiscovery Board is similar to Arduino, we have also looked at Arduino projects similar to ours. Using the research we gathered, we began to look up parts for our robot. Our research was done based on the automation robots and configuring them with the ability to decide based on information they gathered in real time.

1.4 Block Diagram

Following our research, we have developed a block diagram for our robot which can be seen below.



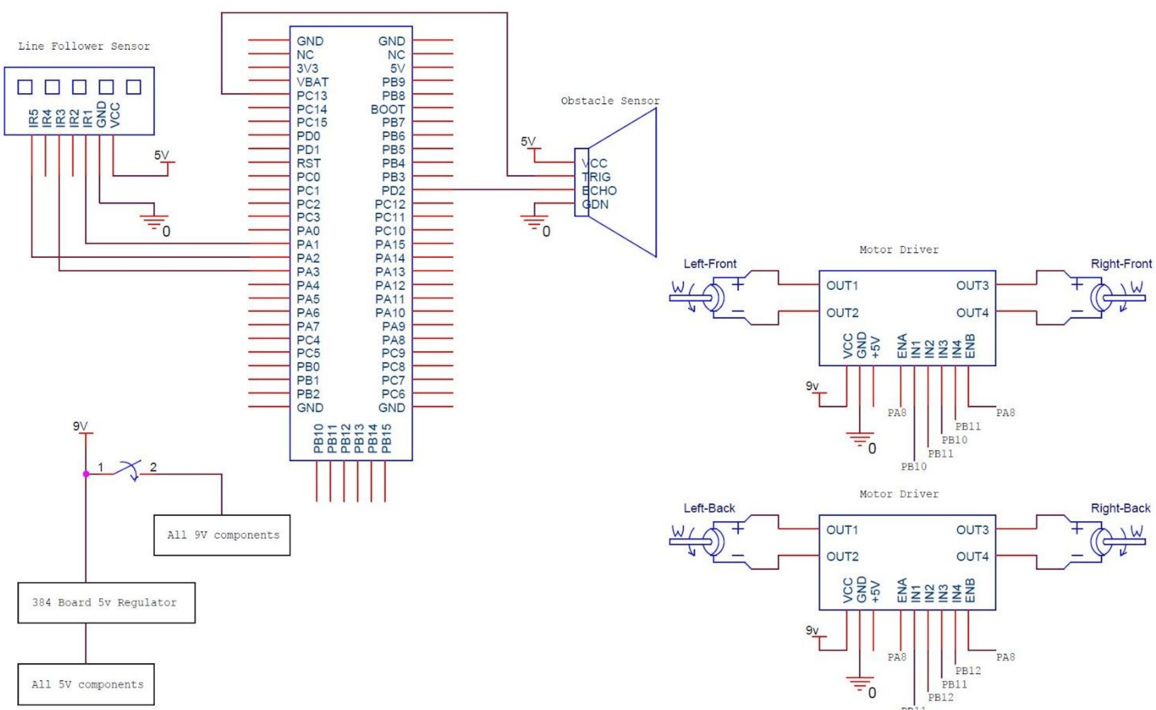
1.5 Parts

Parts were bought online in stores like Amazon and RobotShop. The parts used for this project are as follows:

- STM32VLDiscovery Board and 384 Board
- 4 wheels and chassis
- 2x 9v battery
- 4x DC Motor
- 3x HC-SR04 Ultrasonic Sensor
- 5 channel Tracker sensor
- QRD1114
- L298n Motor Driver
- Breadboard, wires, screws, nuts, and bolts

1.4 Schematic

The full schematic for our robot can be seen below:



Section 2: Operation

2.1 The Robot

The robot is approximately 25cm x 15cm x 12cm (l x w x h). It is powered by two 9v batteries. One is directly connected to the 384 board and the other is connected to the motor drivers with a switch. This battery supplies power to the motor driver and the 5V for sensors comes from the 384 Board power supply. The pictures are added at the end for better understanding and reference.

2.2 The Course

The course for the project is approximately 170cm by 150m. It contains a simple track with diagonal and 90 degree cuts. The track has a dead end and an obstacle at the end. The start of course has a home setting where the robot will start and end at. The track also contains three horizontal lines in the middle which are for the purpose of counting consecutive lines and keeping a count of them. The course will have a black background with white track and lines on it for the robot to navigate.

2.3 How it all works

The whole idea of this autonomous 4x4 vehicle is to gather data from its surrounding and based on that follow the instructions it is programmed to do so. The robot has two major real time sensors one is the set of 3x HC-SR04 Ultrasonic Sensor which are mounted on front, left and right side of the vehicle. The robot also contains a channel of 5 tracker sensors mounted at the front bottom of the vehicle that detects the difference in color of ground by detecting the amount of signals it sends and receives. The idea for the vehicle is to be able to gather information from its sensors and navigate through a course.
At the home location from where all the ground is white the sensors read the data and acknowledge the command of delaying its actions for a certain period of time. After that the obstacle avoidance mode which is based on ultrasonic sensors will take charge and it will move towards the direction of larger space. The moment when the IR sensor reads the difference in color it will take the control and navigate the robot. The IR sensors are also configured with a line counter mode that can be turned on and off with a dip switch. This mode counts the change in colors in less than 10 sec and evaluates and then keeps repeating once the count is complete it will end the line counter mode.

When it comes to giving commands to the motor the ultrasonic and ir sensor works as input and the microcontroller gives output command to the motor driver this L298n Motor Driver controls the forward and backward motion along with the speed of the motors. The forward and backward motion are just based on logic high or low. Whereas the speed of the motors are controlled using the pulse width modulation feature of stm32 microcontroller board.

The navigation of the robot by these sensors and their working is explained in the following sections.

2.4 Obstacle Sensor

The schematic shows the layout of connections made between microcontroller and obstacle sensor. The obstacle sensor or ultrasonic sensor basically uses a signal sent out from trig and waits for it to come back while the counter runs and receives at echo. The sensor mounted on the vehicle continuously reads the distance and when an obstacle comes in 10 cm of the sensor they take control over IR sensors and do a 180 degree spin until the IR sensor catches its value.

2.5 Motor Driver

The motor driver takes a 9v voltage source and it also takes a 5v logic voltage from 384 Board. The reason why it’s called a motor driver is because it controls the speed and direction of the motors according to values taken from IR and ultrasonic sensors.
The motor driver also takes a PWM input from the microcontroller which helps control the speed depending on how much pulses we allow it. For example 50% duty cycle is high for half the time and low for the other half.

2.6 IR Sensor

The IR sensors play a very important role in the navigation of this vehicle. As mentioned before out of the 5 channel tracker sensor we use the middle one to navigate forward direction mainly. Our far left and far right are for right and left turns according to the track. The chart below helps understand the signals based on three sensors and the data manipulated by the motors from these sensors.

colors	Left Sensor	Middle Sensor	Right Sensor	
All Black	0	0	0	reverse
Right = white	0	0	1	right
Middle = white	0	1	0	forward
Middle,right = white	0	1	1	Right corner
Left = white	1	0	0	left
n/a	1	0	1	none
Middle,left = white	1	1	0	Left corner
All White	1	1	1	home

Section 3: Testing

3.1 Testing the Motors and Motor Drivers

Before the motors are connected to the motor drivers, we directly supplied variable voltages to see if they all work properly in forward and reverse modes. Once we determined that the motors are working properly, connected them to the motor drivers which are connected to the STM32 Board.

To test the PWM with the motors, we have used the dip switches as input. The values for PWM are 0%, 33%, 66%, and 99%. Furthermore, the PWM output is connected to the oscilloscope for further testing.

3.2 Testing the Obstacle Sensor

Testing the obstacle sensors were divided into three parts: testing the Trigger, testing the Echo, and testing all three obstacle sensors together.

To test the Trigger, we connected it to an oscilloscope to see if it is providing 60us output.

To test the Echo, we connected a led and configured it such that upon receiving a signal after colliding with any object between the sensor and object it should turn on the led. Second step was to configure the sensor to count the time it takes from sending the signal and receiving it back. This will give us time and from that we can used the famous S = V X T equation to calculate distance and in this case the velocity is speed of sound that is 343m/s

3.3 Testing the IR Sensor

At first, we used all five IR sensors in the array. Upon further inspection, we realized that having five sensors is overkill in terms of the scope of the project. That said, we disconnected the second and fourth sensor from the system. Furthermore, we thought that our IR sensors are digital inputs. When we connected a DMM to one of them, we realized that they are analog instead.

To test the IR sensors, we printed off a piece of paper with black and white lines. We used the LCD from the 384 board to display the direction of the lines.

The table below shows the cases that will be shown based on the input from the sensors.

Left Sensor	Middle	Right	LCD Output
Black	White	Black	FORWARD
Black	White	White	RIGHT
White	White	Black	LEFT
Black	Black	Black	NONE
White	White	White	NONE

3.5 Testing the Whole System

While putting together the robot we tested each of its components separately. The connection of motors with the data gathered by IR sensors. The motion of the motor in relative directions based on the distance collected from Ultrasonic Sensors were all tested. The complicated part was to get them to work side by side. We started with a smaller portion of our track and decided to evaluate the outputs and then give each sensor specific set of instructions.
The hardest part was turns so we came up with the idea of moving forward when (010) refer to the table in IR Sensors. This means that it moves forward when the middle reads the voltage less than 2.5 and the point where it reaches the turn andreads (011) that's a right turn. Since the motor has a speed and it won't slow down so we programmed 000 all black to be the reverse and keep reversing until

any of the sensors reads the track again and keeps repeating the steps until the middle one is forward and the other two are black.

Section 4: Future Plans

4.1 Areas of improvement

As there is always room for improvement we are working on bringing new updates to our current software which will help the vehicle be more efficient in navigating and reduce the time it takes now to decide its course of action.
We will also be looking at possible solutions to add more features to the robot for example detection of light and recording the temperature at a certain place.
The possibilities are endless and this is just the beginning of this little 4 wheeler.