Preliminary Design Review (PDR)

Food Delivery Bot

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Abstract

Demand for contactless delivery services has been massively surging during the COVID-19 pandemic and expected to keep increasing after. With that said, we decided to pursue the design and implementation for a delivery bot which is exclusively used for the food delivery industry. Our bot will be capable of moving autonomously from one point to another point and back to initial position, avoiding obstacles, stairs, holes, locating real-time position, keeping food warm (hot) and providing a secure way of food delivery. Arduino Uno is the main controller for our system along with ultrasonic sensors, L298N motor drive controller, four DC motors and two 9V alkaline batteries. As of now, we were able to achieve most tasks we set but the PID controller simulation. PID is the biggest challenge we have to tackle. The second prototype is expected to be much different and more advanced from the first version. Wifi and GPS will be integrated in the system to provide better communication and localization capability. We will also be looking into various path finding algorithms for our bot. Deploying IR sensors and PID controllers would be crucial in this prototype to allow our bot going in the desired route. Ultimate goal is to make our bot autonomous.

A. Mission

The world has been facing the toughest challenge ever in history which is the unexpected battle against COVID 19. It has changed the way our world operates. Social distancing has been strictly implemented. Direct human-human contact has been limited. More ways of contactless communication are encouraged to ensure safety, which is mainly to slow down the spread of this virus in our community. Contactless delivery has emerged to fulfill human needs in many areas, including food, mail, grocery, and so on. This facilitates human access to essential goods and food during the circumstances involving a lot of restrictions from the government to fight against the virus. Demand for it has surged massively due to the pandemic (Bernard Marr, 2020) and will keep increasing in the next coming years as per the report by Facts & Factors (2021). For that reason, our team is building a robot for contact-free food delivery. Our main objective is to design and implement a bot which is capable of moving from one point to another point and back automatically while avoiding objects, stairs, holes, keeping food hot (warm), and being locatable.

Big companies in the food delivery industry, such as Grubhub and Doordash, are using robots for delivering food in some places (Hawkins, 2021). There have been a bunch of food delivery robots implemented by reputed companies, such as Starship, Kiwibot, OzRobotics etc. Since there are still an abundant amount of restrictions, including security, communication, lack of confidence in robotics from client’s sides, dealing with traffic and requiring of high-tech devices knowledge, delivery robots have not been used widely yet, mostly for business districts and school campuses. The high initial cost (starting at 5,000$ and up to 50,000$) of purchasing a delivery robot also takes into account restaurants owners' hesitation. Our goal is to provide a cost-effective, and user-friendly solution to overcome drawbacks of food delivery robots.

Requirements Traceability Matrix

	Requirements	Derived Requirements
1	Obstacles avoidance	• Ultrasonic sensors sensors employed for distance detection to any obstructing objects • Robot will change direction if objects are detected close by 35 cm (approaching customer is the exception)
2	Ability to keep food warm/cold	• Insulated food compartments with multilayer insulation • Material: foil, heavy vinyl or waterproof and heat reflective plastic wrap • Keep warm up to 1 hours, cold up to 2 hours • Dimensions: 9-1/2"W x 7-1/2"H x 7-1/2"D
3	Controllable speed	• Programmable driver motor shield • Robot operated by 4 motors • Speed range: maximum up to 2 mph
4	Trackable (TBD)	• GPS integrated to allow both restaurants and customers track real time location • GPS helps to navigate the robot, find the path to the destination and go back to the original point by providing geolocation (longitude and latitude coordinates) • Range: within 3 miles (business districts or school campuses)
5	Friendly communication protocol with both client business side (TBD)	• Website/ Application • Send messages for notification

B. Proposed Design

I. Description of systems

Our food delivery bot will receive requests from the merchants through a smartphone application or a website to start with information including geocoordinates (latitude and altitude) of both current and target location. Microcontroller will use that information to guide the robot to the destination and go back to the initial point by using a compass for orientation, programmed shortest path finding algorithms and sending corresponding voltage input to the motor driver L298N to control the motors. While the bot is moving, ultrasonic sensors and IR sensors will be constantly sending data to the Arduino for obstacle avoidance and to follow a specified path. We will be also programming a PID control algorithm for our Arduino Uno microcontroller to control the speed of the motors. PID will help reduce the error to ensure that the robot will be able to move on the desired path. When it goes too much left, too much right, too fast, PID will alter the left and right motors speed in order to have the bot back to the right direction. Inputs for the PID include the data from ultrasonic sensors and IR sensors. Two 9 V AAA batteries will be used to power the motor driver as well as the Arduino Uno.

II. Budget/ Materials

This table below shows the necessity parts and their approximate cost for the first prototype.

Key	Item	Amount	Cost per	Total cost
A	Ultrasonic sensor (Sensor Mount Included)	3	$2.40	$7.20

B	DC Motor and Smart Car Wheel Compatible (Wires Included)	1 KIT	$16.99	$16.99
C	IR sensor	2	$0.83	$1.66
D	Breadboard	1	$1.75	$1.75
E	9V Battery	2	$4.99	$9.98
F	Microcontroller (ELEGOO UNO R3)	1	$13.99	$13.99
			TOTAL	**$51.57**

III. Gantt Chart

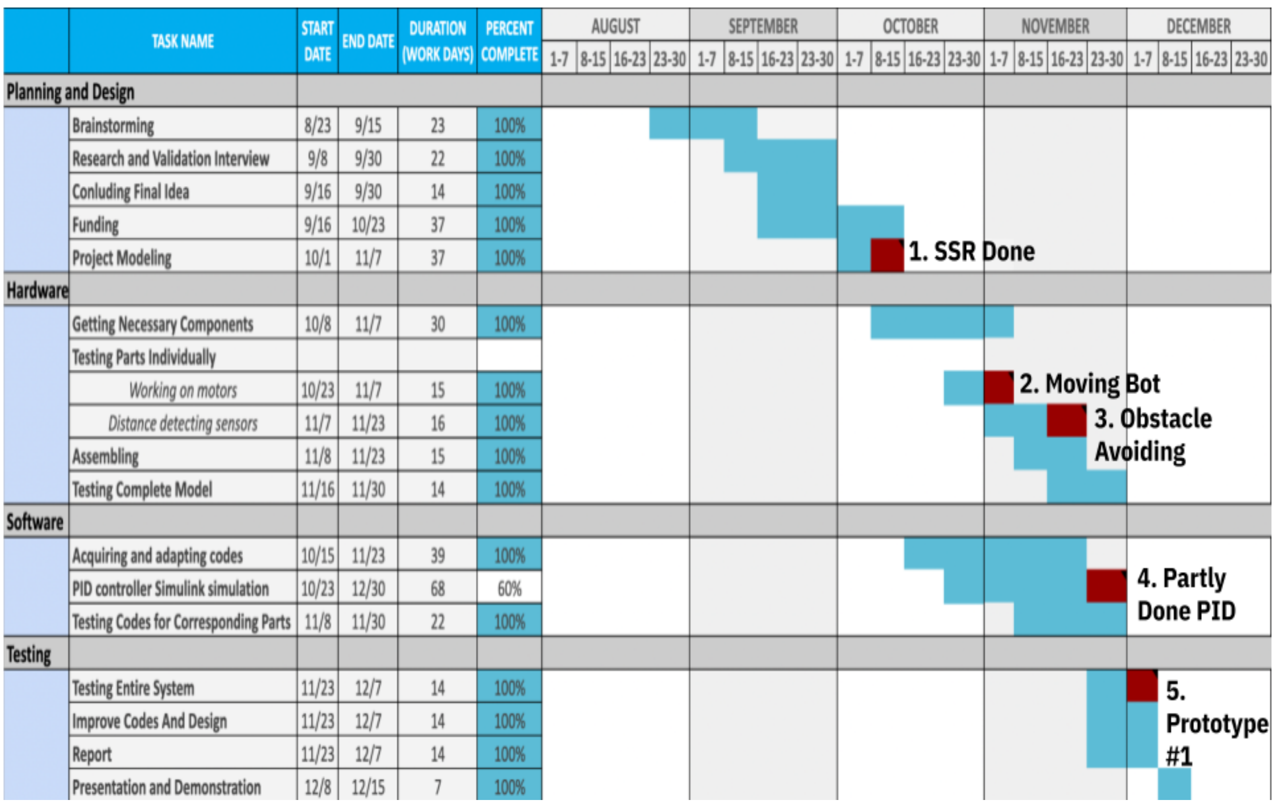

Figure 1: Gantt Chart with Weekly Updates

There are 4 important milestones in our projects:

1. Completing the SSR which involves initial design, gantt chart, block diagram and requirements traceability matrix.

2. Getting the bot moving (forward, backward, left and right).
3. Finishing the initial research and simulating the PID controller.
4. Completing the first prototype.

IV. Block Diagram

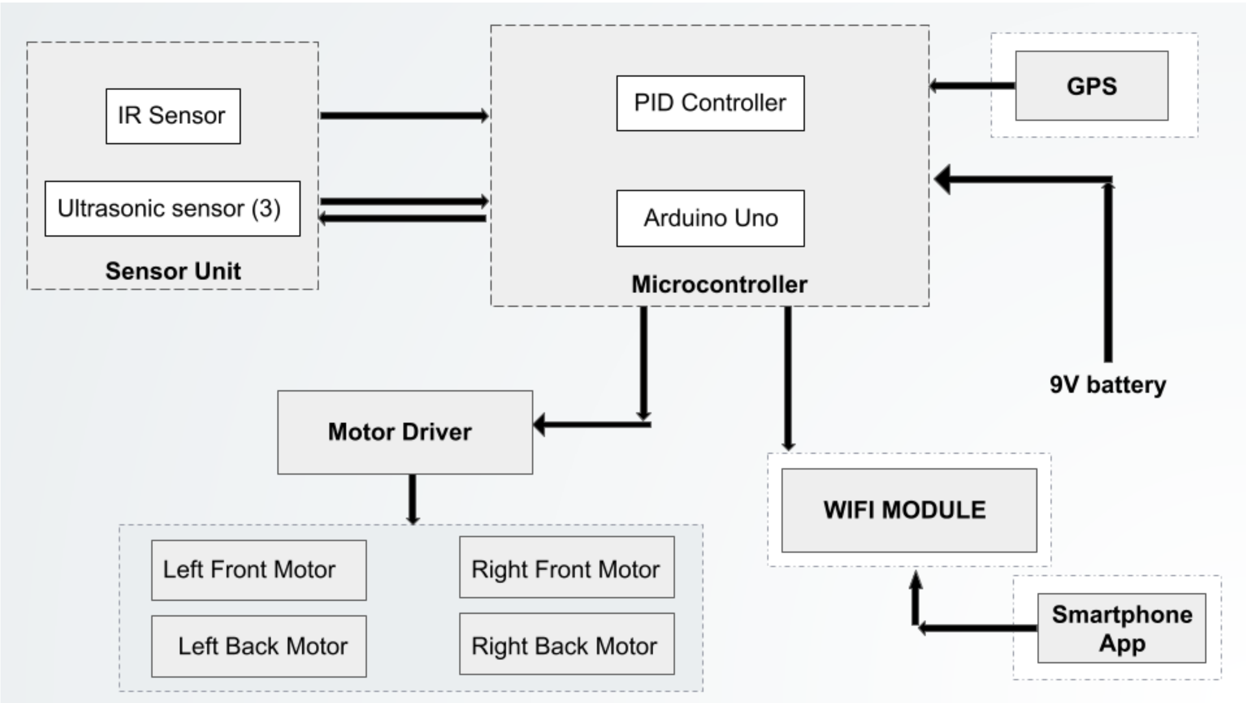

Figure 2: System Block Diagram

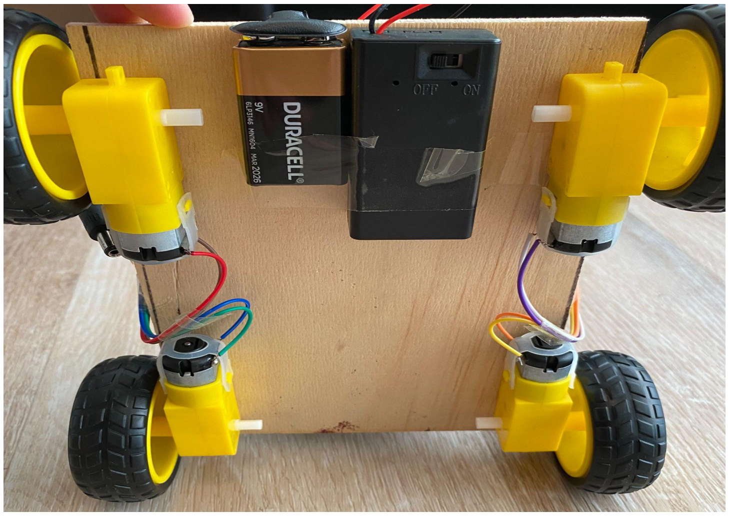

Figure 3: Back Side of the Bot Showing Motor Connection and Batteries

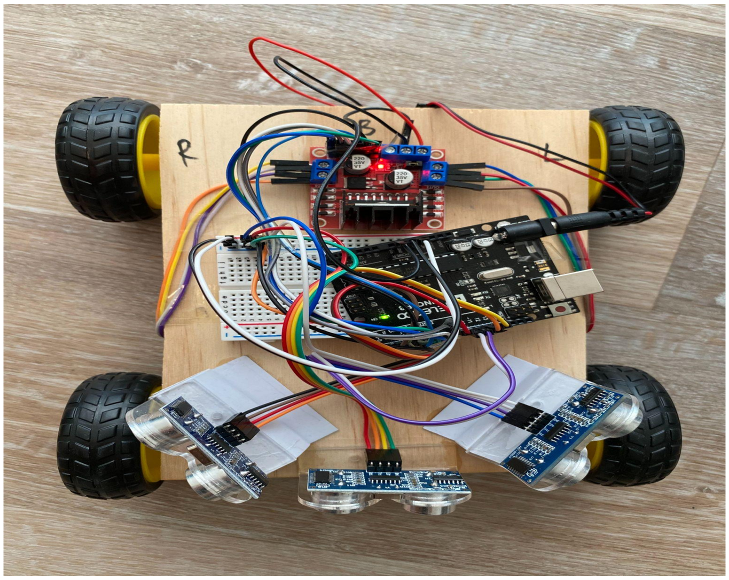

Figure 4: Top Side of the Bot Showing how Parts Assembled

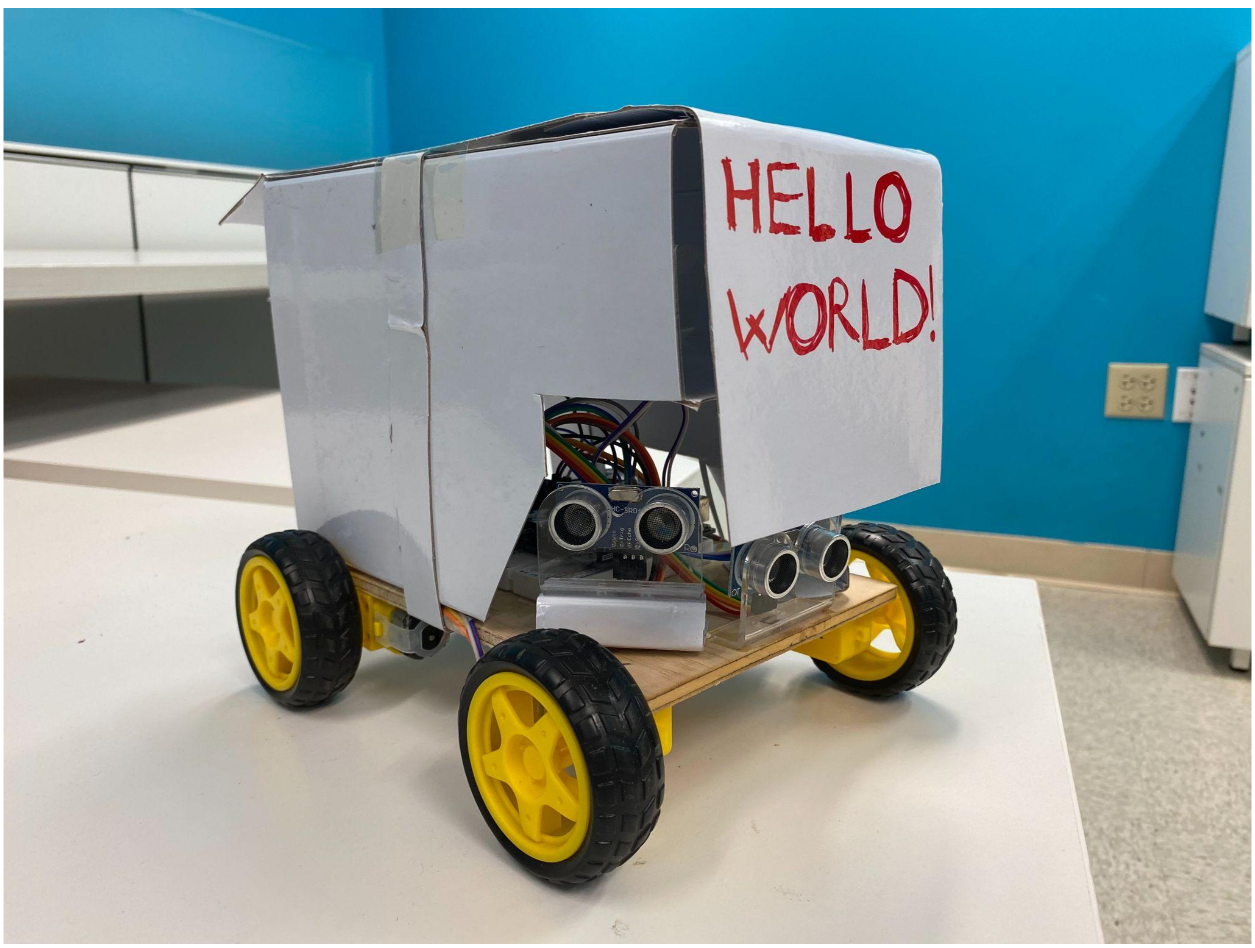

Figure 5: Complete Model for Prototype 1

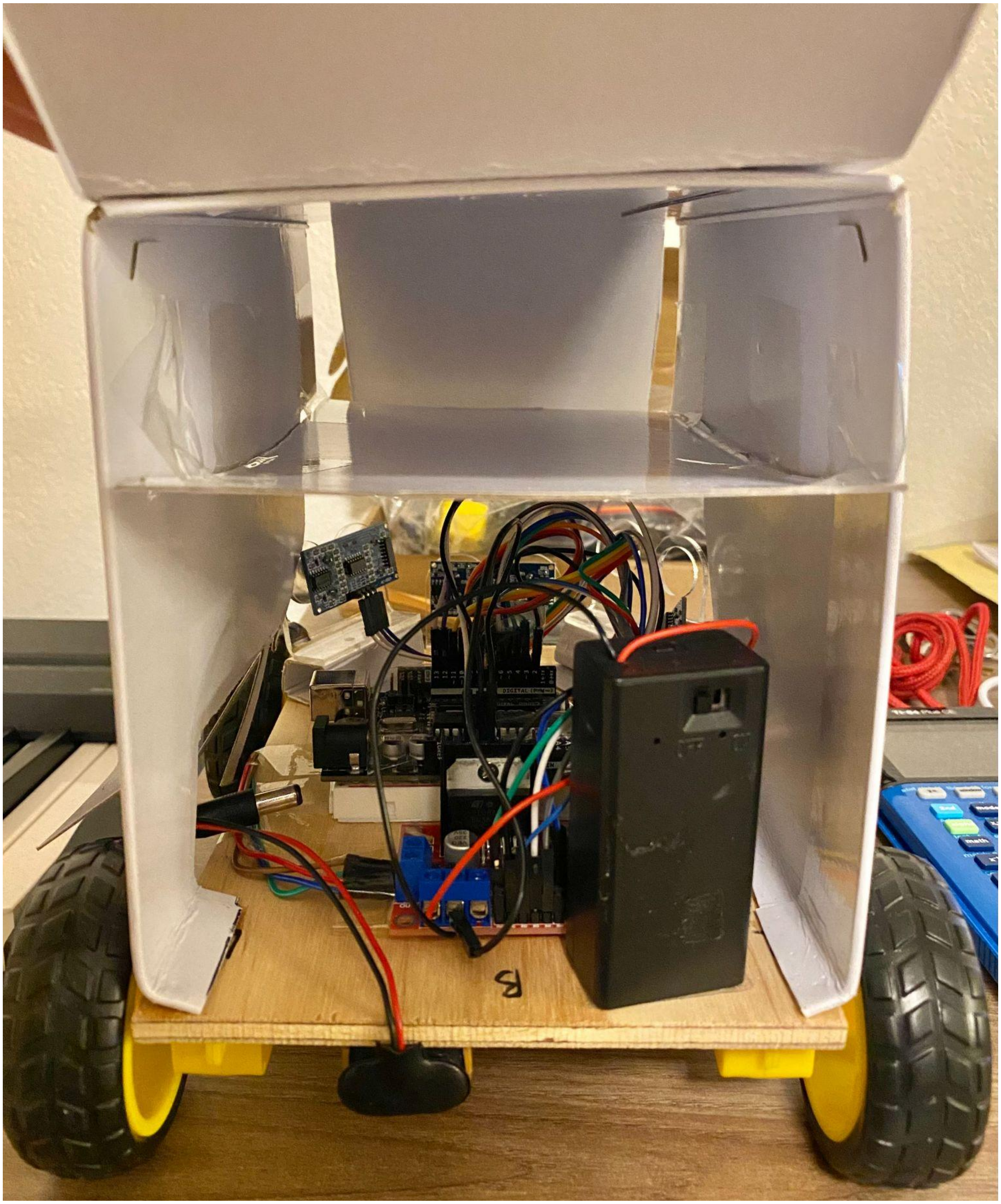

Figure 5: Back Side of the Bot Showing Two Separate Compartments for Electronic Parts and Food.

V. Current work:

We basically finished our first prototype. Most of the requirements for this first version have been fulfilled. Our bot is able to move forward, backward, turn left and right in every corresponding circumstance (obstacle in front, on the left or right). It has capability to detect objects in front, on the left and right by 3 ultrasonic sensors mounted on the head. The speed of the motor is adjustable by the motor driver receiving variable inputs from the Arduino Uno when a specified condition is met. Specifically, when there is an object in front of the bot and within 35 cm, the arduino will send signals to the driver to stop the motor, move backward a little, check distance on the left and on the right, whatever direction is clear, the bot will turn to that direction and continue moving forward. The process above keeps repeating to ensure the bot won't hit any obstacles.

PID controller: we have simulated some models in Simulink. For simplicity, we first started with the P controller. Inputs are data from ultrasonic sensors and IR sensors. We use step responses to represent the inputs for the controller. Some results are shown below.

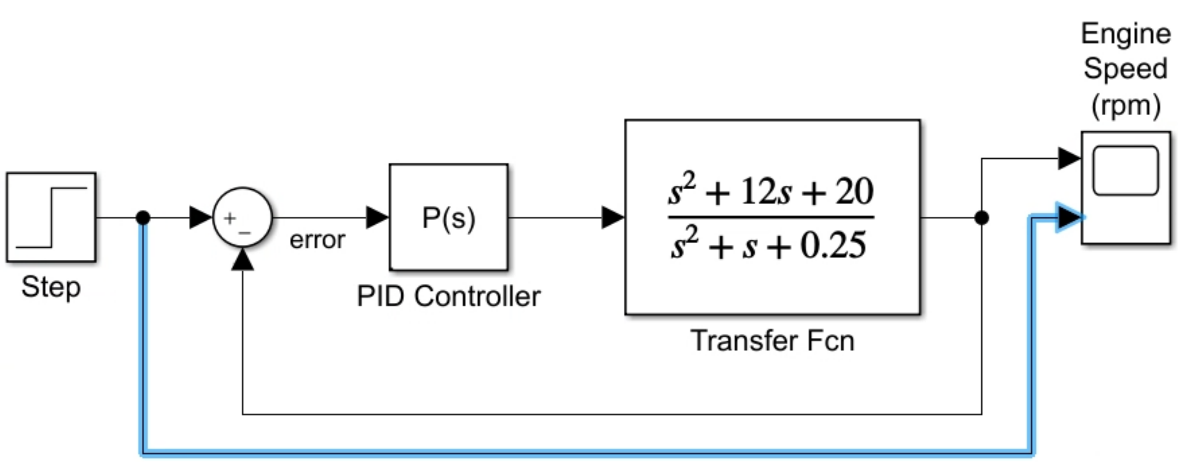

Figure 7: Sample P Controller Model

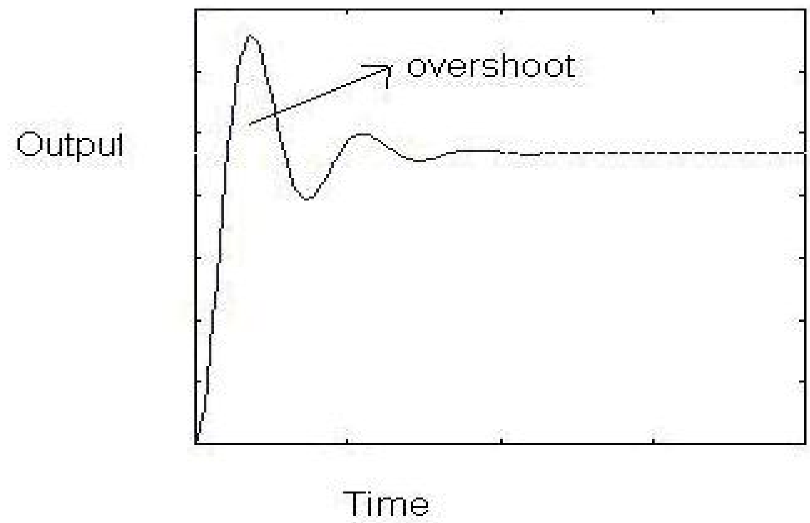

Figure 6: Output of P control

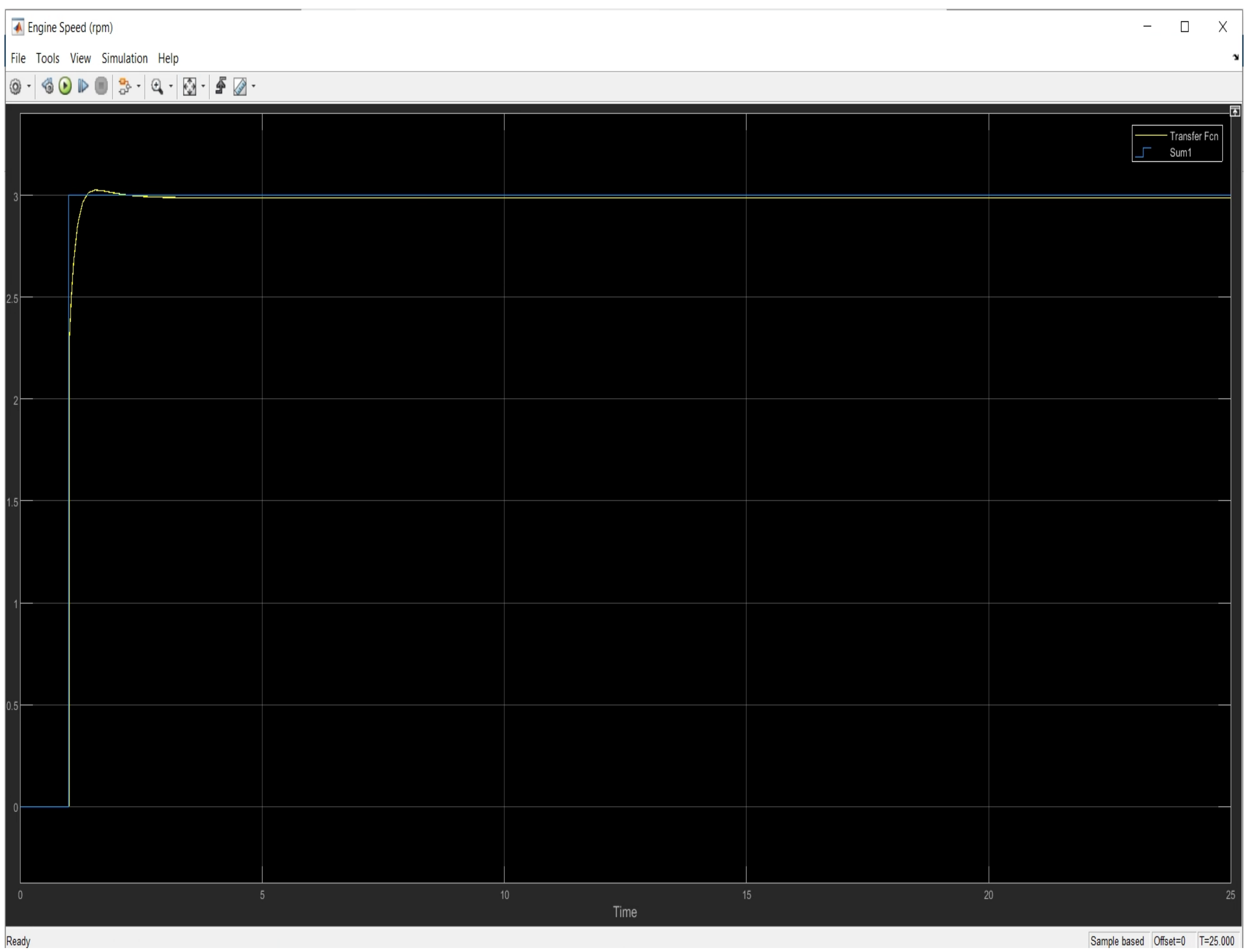

Figure 7: P Output

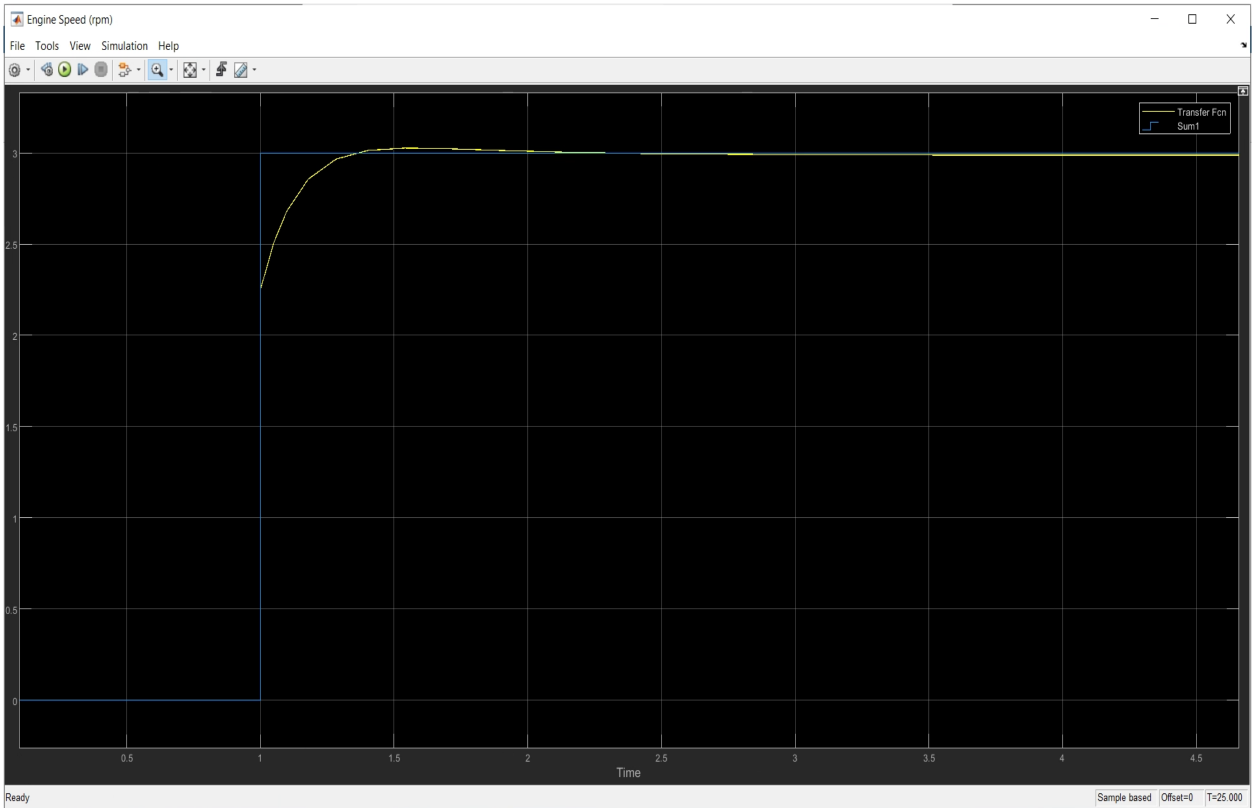

Figure 8: P Output

Issues and Solutions: there were some minor issues we had to deal with:

- We initially put one ultrasonic sensor in the front which can only detect within 30 degrees. We couldn't monitor the left and right sides of the bot, therefore, we decided to attach 2 more ultrasonic sensors to the left and right side. That helped widen the detection angle.
- One of the ultrasonic sensors wasn't sending data, so we checked the wiring connections and PIN defining on the code. It worked after we rearranged all the wires to different pins on the arduino.
- Motor driver stopped working and had a continuous beeping sound. We checked all the connections of the motors to the driver, soldered points to make sure

everything was connected and changed the battery. It was working again as expected.

- The biggest challenge for us was to deal with the PID controller. To tackle this problem, we had to get references from books, YouTube videos, PID documentation on Simulink, and pre-built models.

VI. Future work:

We will be advancing our robot to another level in the next prototype. We will implement a PID control algorithm (P control) to control the speed of DC motors to reduce error close to 0. GPS is also necessary for localization and navigation for the bot. In order to better communicate with the bot, Wi-Fi will be integrated in the system to connect the bot to a pre-built IOT app (BLYNK). That way, either merchant or client will be able to interact with the bot easier. To accommodate a better design for our bot, we are planning to make some 3D printed parts instead of the cardboard box we were using in the first version. It is extremely essential to program a path finding algorithm for the bot based on the longitude, altitude and compass.

References

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