Automated Driving Using External Perception

Individual Lab Report - ILR01
February 9, 2023

Team E - Outersense

Author:
Dhanesh Pamnani

Team Members:

Atharv Pulapaka
Ronit Hire
Jash Shah
Shreyas Jha

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1 Individual Progress

1.1 Sensors and Motors Lab

I worked on the SHARP IR Sensor and on removing the debounce from the system as well as integrating the push button and potentiometer in the system. I further was responsible for developing the Skeleton Code for State Machine and helped in the PID tuning.

1.1.1 SHARP IR Sensor

For integrating the SHARP IR sensor I started with reading and understanding the data sheet. The data sheet talks about the range of the sensor from 10cm to 80cm. It further tells us about the the Judgement distance as 24 cm and type of judgement. I used this to plot the transfer function of the IR sensor.
For this I used a reflecting surface as recommended by the data sheet and mounted the sensor on a desk. I then used a measuring tape and measured the response of the analog sensor after connecting the it to the micro-controller and providing the necessary voltage (5V). The transfer function is shown below

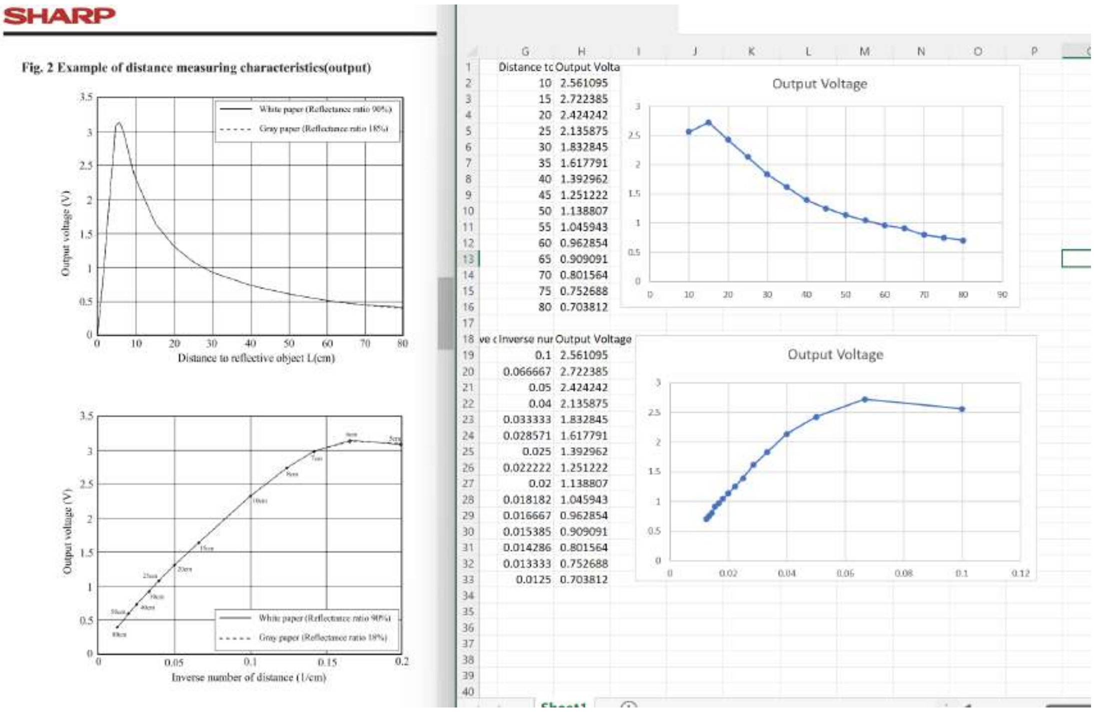

Figure 1: Transfer Function: Data sheet vs Obtained

As can been seen from the image above the transfer function obtained is very similar to the one in the data sheet. The image also shows the data that was collected to obtain the transfer function. I placed the reflective sheet at known distances and obtained the readings as seen above

Further I worked on the state machine and removing debounce form the system. The details are briefly touched upon in the following section.

1.1.2 State Machine and Debounce

For the state machine the code starts in the library mode and on pushing the button goes in the Calibration Mode. I worked on the debouce in a way that any signal after 200 micro seconds would be considered as a separate input and would be processed, however any input within the margin would be ignored.

The final setup can be seen below:

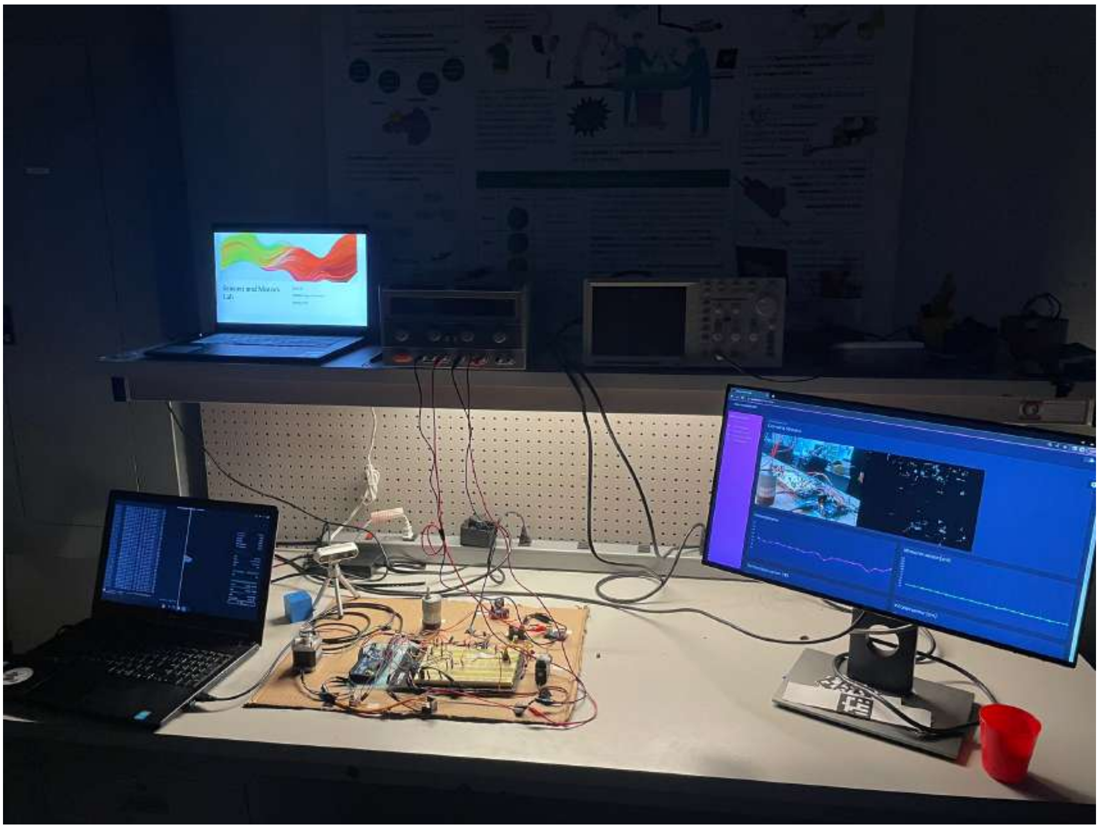

Figure 2: Team E: Setup for sensor motor lab

1.2 MRSD project

I have mainly been working on the project management and mechanical engineering with respect to the MRSD Project. I started with the CAD design of the modular track and the infrastructure design - as seen below. The track was designed in a way to account for modularity, that would allow the team to setup the track and move it around with ease. The infrastructure has been designed to allow the camera to move from 2.5m to 3m in height to cover the different track layouts. I started the process by designing the car in Solidworks and conducting a few experiments to understand the FOV of the Realsense camera and the turning radius of the RC car. These values were used to understand the area that would be required to set the track and the height of the infrastructure that would be needed to capture the entire track. The design began by considering the budget and the available materials in the inventory. I also have been working on the project management of the team, I am primarily responsible for the budget and inventory of the team. I am also responsible to ensure that the team has defined goals that are reachable but also ambitious to make sure that the team makes progress with respect to the Minimal Viable product

while also striving to achieve the targets within the deadlines. I have also been involved and am helping Atharv in the Simulink Simulations and plan on working on the perception system as soon as the manufacturing of the track and infrastructure is completed.
The picture below shows the modular track that we are building

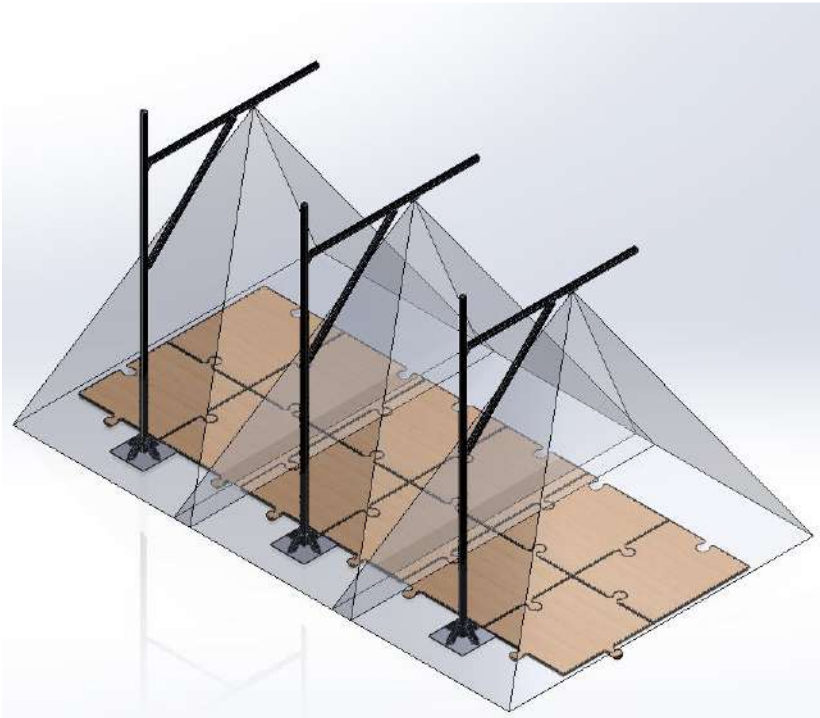

Figure 3: Team E: Track Infrastructure CAD

2 Challenges

2.1 Sensors and Motors Lab

The challenges in generating the transfer function was taking accurate readings. one challenge was mounting the sensor such that the sensor stays stationary when the readings are taken. The IR, state machine codes worked perfectly in my system however on integrating it in my teammates system the code failed to run. We were able to figure out that the libraries downloaded were different. One key take away was ensuring that the libraries downloaded are consistent in every system

2.2 MRSD project

Some challenges that we have faced so far include the challenges in setting up the track in a fixed place at B level. We wanted to go ahead and work such that the track does not need to be put together every time and hence got the permission to use the B512 lab. However we later realised that the track would need to be modular and would need to be set up outside the Navalab. Secondly, the challenge of setting the infrastructure has been substantial. Tim Angert has been a huge help on this front for the team. Lastly, when changing from Brushed motor to Brushless DC Motor the team chose to go ahead with a VESC which also has low level control on it, however we have been facing a lot of issues in setting it up and using it for our system. We have been coordinating with other labs that use VESC to get a potential solution to this problem.

3 Team Work

This section talks about the work the team members have been doing in the Sensor Motor Lab and the project.

- **Jash Shah**: Jash worked on the PID control of the DC motor. He was primarily involved in writing the control part of the sensor motor lab assignment with Atharv. Jash has been working on the perception font of the project where he has worked on the initital steps of pose detection on a table test model.

- **Shreyas Jha**: Shreyas worked on integrating the Ultrasonic sensor with the stepper motor and was primarily responsible for the integration of the entire code. He helped me with the IR sensor set up and obtaining the transfer function. He has been working on setting up the RC car and customising it as would be required for the project. He has been working on the VESC and also on integrating the BLDC motor instead of the brushed motor.

- **Ronit Hire**: Ronit worked on the GUI of the Sensor motor lab. He also has been helping all the other team members with their work and has been a key team player. He helped debug the PID control and also helped in integrating the final code. On the Project front Ronit has been involved in the Mechanical design with me along with project management. He has also helped Atharv in the Simulink Simulations and Jash in perception.

- **Atharv Pulapaka**: Atharv worked on the overall circuit design and debugged the hardware issues that came up through out the Sensor Motor Lab work. He also worked on interfacing the servo with Arduino and implemented the Servo Sweep with me on the IR sensor. Atharv has been primarily involved in understanding MPC and the latency budgets that the other systems can have. He has been working on Simulink Simulations of the car and the track.

4 Plans

The path forward for the team can be divided in various fronts

- **Mechanical**: The team will be focusing on getting the track ready and the infrastructure setup with the sensor and the computing system. The main driving factor is that the testing of the cars on the track should begin as soon as possible to understand the effect of the variability of the real world in our system.

- **Car Customization**: The car would be worked on in the following month to make it ready to be teleoperated by including a Power Distribution Board and a Real Time clock along with the micro-controller, BLDC and other modifications on the mechanical front.

- **Perception**: The pose and velocity of the vehicle needs to be ascertained through the perception system. The next steps is breaking this down into smaller more manageable tasks with set goals and working on them.

- **Controls**: On the controls front the main focus will be to understand the latency budgets and start working on the MPC blocks of the sub-system

5 Sensor Motor Lab Quiz

1. **From ADXL335 accelerometer datasheet**

   - **What is the sensor's range?**
     A. -3.6g to 3.6g is the typical range

   - **What is the sensor's dynamic range?**
     A. 7.2g is the Dynamic Range

   - **What is the purpose of the capacitor CDC on the LHS of the functional block diagram on p. 1? How does it achieve this?**
     A. The capacitor reduces the effect of noise from power supply on sensor reading by acting as a filter. Sudden changes to voltage across the terminal of the capacitor has no effect on it

   - **Write an equation for the sensor's transfer function.**
     A. $V_{out} = 1.5 + 0.3 * a$

   - **What is the largest expected non-linearity error in g?**
     A. The full scale non-linearity is 0.3%,
     this equates to $0.3\% * 7.2 = 0.0216g$

   - **What is the sensor's bandwidth for the X- and Y-axes?**
     A. 1600Hz is the bandwidth for the X- and Y- axes of the sensor

   - **How much noise do you expect in the X- and Y-axis sensor signals when your measurement bandwidth is 25 Hz?**
     A. Noise of ADXL335 is typically given by $rmsNoise = NoiseDensity * \sqrt{1.6 * BW}$
     Hence, 948.68 μg is the expected noise

   - **If you didn't have the datasheet, how would you determine the RMS noise experimentally? State any assumptions and list the steps you would take.**
     A.Place the sensor on a flat surface and esure there is no motion.
     Taking squareroot of the mean of the values obtained when there is no motion will give the RMS noise

2. **Signal Conditioning**

   - **Filtering**
     1. Name at least two problems you might have in using a moving average filter.
     A.
     i) When dealing with high frequency signals the large window size leads to large data
     ii) The large data traveling due to large window size can cause lags

     2. Name at least two problems you might have in using a median filter.

A.
i) It is computationally expensive to calculate median in a moving stream of data
ii) The features such as peaks are lost as they are not tracked

- **Opamps**
  In the following questions, you want to calibrate a linear sensor using the circuit in Fig. 1 so that its output range is 0 to 5V. Identify in each case: 1) which of V1 and V2 will be the input voltage and which the reference voltage; 2) the values of the ratio Rf/Ri and the reference voltage. If the calibration can't be done with this circuit, explain why.
  Case 1: Range = -1.5 to 1.0V
  Solving Opamp equation below

$$\frac{V_1 - V_2}{R_i} = \frac{V_2 - V_{out}}{R_f}$$

$$\frac{R_f}{R_i} = -2k\Omega$$

when $V_1 = V_{in}$ and $V_2 = V_{ref}$, This however is not possible,
We can also use $V_1 = V_{ref}$ and $V_2 = V_{in}$

$$\frac{R_f}{R_i} = 1k\Omega$$

Hence, V_1 and V_2 as input can lead to calibration

Case 2: Range of -2.5 to 2.5V
Solving Opamp equation below:

$$\frac{V_1 - V_2}{R_i} = \frac{V_2 - V_{out}}{R_f}$$

$$\frac{R_f}{R_i} = -1k\Omega$$

when, $V_1 = V_{in}$ and $V_2 = V_{ref}$ This is however not possible, alternatively, we can use $V_1 = V_{ref}$ and $V_2 = V_{in}$

$$\frac{R_f}{R_i} = 0$$

Thus, R_f has to be 0 or R_i has to be infinite, both of which are not possible. Hence, we cannot calibrate

3. **Control**

- **If you want to control a DC motor to go to a desired position, describe how to form a digital input for each of the PID (Proportional, Integral, Derivative) terms.**
  A. Proportional term scales the error between the input and observed value and helps in determining the responsiveness of the system.The integral term accumulates errors and drives it to zero and the next time step moves from this step. The derivative term defines

the rate of change of error with respect to the previous error. In our case it affects the acceleration of the system.

- **If the system you want to control is sluggish, which PID term(s) will you use and why?**
  A. The Proportional term scales the error for input and can help make the system less sluggish as it reduces the rise time

- **After applying the control in the previous question, if the system still has significant steady-state error, which PID term(s) will you use and why?**
  A. The integral term can accumulate errors and drive it to zero at steady state and hence the 'I' term is what I will use

- **After applying the control in the previous question, if the system still has overshoot, which PID term(s) will you apply and why?**
  A. Overshoot can be tackled with a damper, hence the 'D' term is what I will apply

6 Code

```
const int statebutton = 2;  // push button to
change states
//IR
#include <SharpIR.h>
#define IRPin A0
#define model 20150
int distance_cm;
/*
Model :
GP2Y0A02YK0F --> 20150
GP2Y0A21YK0F --> 1080
GP2Y0A710K0F --> 100500
  GP2YA41SK0F
--> 430
*/
//
Create a new instance of the SharpIR class:
SharpIR
mySensor = SharpIR(IRPin, model);
bool state = false;
void setup() {
  pinMode(2, INPUT);
  pinMode(A0,INPUT);
  attachInterrupt(digitalPinToInterrupt(2), change_mode, CHANGE);
  Serial.begin(9600);
}
void change_mode()
```

```
 {
  static unsigned long last_interrupt_time_mode
= 0;
  unsigned long interrupt_time_mode = millis();
  if (interrupt_time_mode −
last_interrupt_time_mode > 200)
  {
  state = !state;
  }
last_interrupt_time_mode = interrupt_time_mode;
 }
void loop() {
  if(state)
  {
    Serial.print("Raw Voltage = ");
    Serial.println(map(analogRead(A0),0,1023,0,5));
  }
  else
  {
    Serial.print("IR distance in cm = ");
    Serial.print(mySensor.distance());
  }
}
```