Automated Driving Using External Perception

Individual Lab Report - ILR03

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Team E - Outersense

Author:

Jash Shah

Team Members:

Atharv Pulapaka
Dhanesh Pamnani
Jash Shah
Ronit Hire
Shreyas Jha

Carnegie Mellon University

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1 Individual Progress

I have primarily focused on two main areas for the MRSD project: developing the perception stack and managing the manufacturing of the track setup.

1.1 Perception

1.1.1 Camera Calibration

From a height of 2.5-3 meters at which the Intel Realsense will be mounted, our software needs to identify a colored identifier and three ArUco markers. Furthermore, using this data, the algorithm needs to calculate the estimated speed as well as the yaw of the vehicle. In order to make sure that these yaw and velocity values are accurate, the cameras being used need to be calibrated. Camera calibration is required so that the pixel in the camera sensor can be mapped in the world coordinate system. To perform complete calibration, the intrinsic as well as extrinsic parameters need to be computed. In order to calibrate the RGB camera of the Intel Realsense, I used a checkboard calibration interfaced in ROS as can be seen in Figure 1(b). I used an 8x6 checkerboard for this iteration and the setup can be seen in Figure 1(a). The reason is that the Realsense has two grayscale cameras which make up the stereo camera and a separate monocular RGB camera. The results of the calibration are shown below:

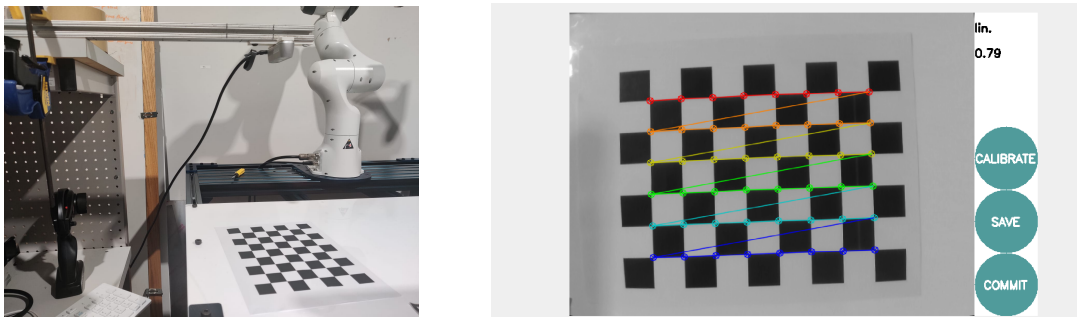
$$CameraMatrix: \begin{bmatrix} 822.04 & 0.00 & 353.65 \\ 0.00 & 827.30 & 177.44 \\ 0.00 & 0.00 & 1.00 \end{bmatrix}$$

$$DistortionMatrix: \begin{bmatrix} 0.17 & 0.88 & -0.05 & 0.02 & 0.00 \end{bmatrix}$$

$$RectificationMatrix: \begin{bmatrix} 1.00 & 0.00 & 0.00 \\ 0.00 & 1.00 & 0.00 \\ 0.00 & 0.00 & 1.00 \end{bmatrix}$$

$$ProjectionMatrix: \begin{bmatrix} 879.52 & 0.00 & 356.15 & 0.00 \\ 0.00 & 878.35 & 167.35 & 0.00 \\ 0.00 & 0.00 & 1.00 & 0.00 \end{bmatrix}$$

Apart from this RGB camera calibration, I also worked on stereo camera calibration. To do this, Dhanesh and I collaborated to use the Intel Realsense off-the-shelf viewer which had three inbuilt calibration processes. The first one we worked on was the on-chip calibration, the second one was focal length calculation and the final one was tare calibration. Using a combination of these three pre-written calibrations, we found the intrinsic and extrinsic matrices of the Intel Realsense stereo cameras.



(a) Before (b) After

Figure 1: Angle detection algorithm performance with change in perspective and lighting conditions

1.1.2 ArUco Marker detection

Along with camera calibration, I also worked on the ArUco marker detection. ArUco markers will be used as fixed markers on the track in order to estimate the pose of the camera with respect to the track and hence, with respect to the identifier on the car. Using 2 ArUco markers and the identifier, the yaw will be calculated. As can be seen in Figure 2, the AruCo markers are detected and the centers of these markers can be further used to create a straight line between the two in order to calculate yaw.

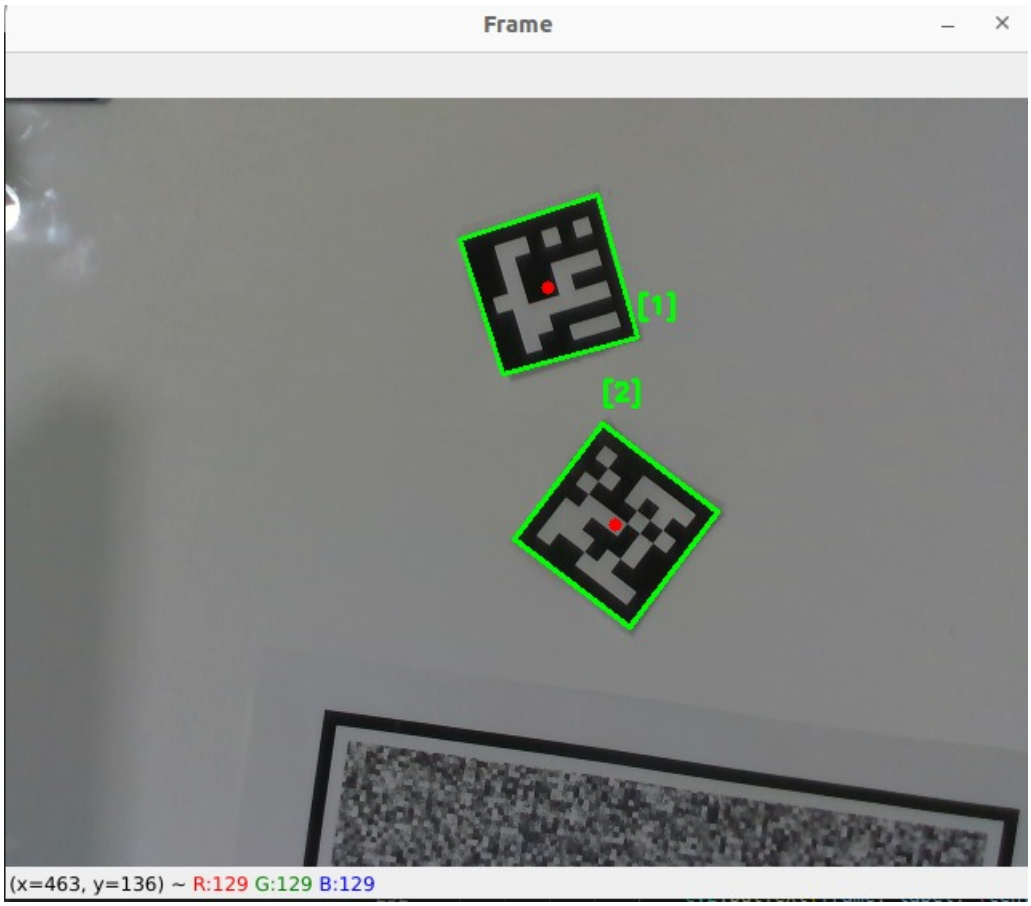


Figure 2: Manufacturing of one of the infrastructure mounts

1.2 Track setup

Before the last Progress review, the manufacturing of one stand was without mounts for the Intel Realsense was completed. This time, I aided Dhanesh, along with Ronit, to complete the manufacturing of the remaining stands. We now have all three stands ready to deploy. Currently, we are testing out different Intel Realsense mounts so that we can choose one which is the most modular and has the best fit. For this purpose, I tried out a few designs, a few of which failed. However, we were able to successfully mount one camera on our infrastructure unit.

Figure 3: Manufacturing of the remaining infrastructure mounts

2 Challenges

2.1 Perception

As for the perception subsystem, a challenge we are facing currently is in the calibration process. We are currently figuring out a system whereby we can corroborate the camera matrix results that we have calculated from the RGB camera calibration as well as the stereo camera calibration. Even though we have a set of values for our camera, distortion, rectification and projection matrices, we are unable to validate these results. Hence, this would be the logical next step for us.

2.2 Manufacturing

On the manufacturing front, even though all the infrastructure mounts are ready to deploy, a challenge we are facing is the wobble of the mount. Because the Intel Realsense is mounted at the edge of the cantilever, there is significant movement in the camera frame when there is even a slight disturbance anywhere on the infrastructure mounts. Our plan is to mitigate this risk by adding sandbags or weights at the bottom of the mount and also changing a few key structural joints.

3 Teamwork

Regarding teamwork, despite having our own areas of expertise, our team is adaptable and works together to efficiently accomplish urgent tasks.

- **Ronit Hire**:Ronit has been actively involved in assisting and providing guidance to all subsystems whenever necessary. He helped Dhanesh and me with the manufacturing of the infrastructure mounts. Moreover, Atharv and Ronit actively worked on trying to explore the use of PID in our system instead of MPC which was deemed to be an overkill. Further, Ronit also helped me in the calibration of the RGB camera.

- **Shreyas Jha**: Shreyas was actively involved in the RC car modifications and interfacing it with a microcontroller. He was able to use the Raspberry Pi to send ROS commands (steering and velocity commands) to the RC car.

- **Dhanesh Pamnani**: Dhanesh was the lead of the manufacturing process. He was in constant communication with Tim so that we could procure parts on time and also use Tim's workshop space at our convenience. Moreover, Dhanesh also helped me in designing the mount for the Intel Realsense, which we were able to deploy on the first infrastructure mount. Further, Dhanesh and I worked on the stereo camera calibration.

- **Atharv Pulapaka**: Atharv, along with Ronit actively worked on using PID to try and control the vehicle in a simulated environment. Moreover, he continued working on the MPC block from the previous week to show significant progress in accurate lane tracking.

4 Future work

4.1 Personal

Regarding my personal involvement, I will maintain my contributions to both the perception and manufacturing subsystems. The perception stack requires some validation in terms of the calibration required. Moreover, the identifier algorithm needs to be seamlessly merged with the AruCo detection code such that everything can be detected robustly at the same time. On the manufacturing front, we will actively try and reduce the vibrations that occur on the infrastructure mounts.

1. Merge the ArUco detection and marker identification code seamlessly such that everything can be detected at the same time robustly.
2. Corroborate the matrices found by one method using some other camera calibration methods.
3. Aid Dhanesh and Ronit in attempting to reduce the vibrations on the infrastructure mounts.

4.2 Team

As for the future work of the team, we wish to achieve the following goals:

1. Generate velocity and steering profile from controls block
2. Attempt to establish communication between two different systems for the RC car using ROS.
3. Further explore PID as an option to control vehicles while continuing work on MPC.