Automated Driving Using External Perception

Individual Lab Report - ILR03
February 16, 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 Manufacturing of the Infffrastructure Units

For this progress review I worked on the Manufacturing of the infrastructure units and the calibration of the camera. The final cantilever setup is shown in Figure 1. The legs were welded on the hollow aluminium pipe and the flat plate at the bottom. The truss was cut of the appropriate length and bolted and revited on the gussests. The cantilever and the truss can move up and down on the hollow frame on the 80-20 attached to the hollow tube. Another reduced height arrangement was made for the camera calibration. This setup will be used for the initial testing of our system too. The camera mounts were 3D printed and bolted to the 80-20. The wobble test and the stability of the stand still needs to be tested and will be tested in the future weeks.

Figure 1: Infrastructure

1.2 Realsense D435i Stereo Calibration

The Realsense camera has 2 types of cameras the RGB camera and the stereo camera for the depth measurements. The camera, due to use over various cycles and many years, looses its accuracy and needs to be re-calibrated. Further if the camera is dropped or stored incorrectly it needs to be re-calibrated. We broke the task into calibrating the stereo camera and calibrating the RGB camera. Jash took over the calibration of the RGB camera. I was responsible for the depth noise, the depth accuracy and the focal length balancing. After going through numerous documents on calibration I decided to go ahead with the on-chip calibration method.
I first started with placing a sample noise printed on a paper on a flat surface at a fixed height from the camera such that the region of interest is >50 percent of the field of view. The depth noise was then calibrated and an estimate of the 2 focal lengths was made. The Figure 2 shows

the noise image used. I obtained the camera intrinsics through this for both the stereo cameras. Next, the depth accuracy was calibrated by placing a marker at a known distance. To increase accuracy we used the geometric projections to obtain the accurate ground truth distance of the target. The formula can be seen in Figure 3. This was then used to obtain the calibrated depth of the camera. A change of 44 percent was seen in the before and after depths of the camera. It was extremely important to keep the camera parallel to the target for this test. Next I worked on the focal length balancing for the 2 cameras. After these were done the health score was calculated for the camera that gave an estimate of the calibration. A score closer to 0 meant that the camera is calibrated properly. The figure 4 shows the health score before calibration and figure 5 shows the score after calibration was done.

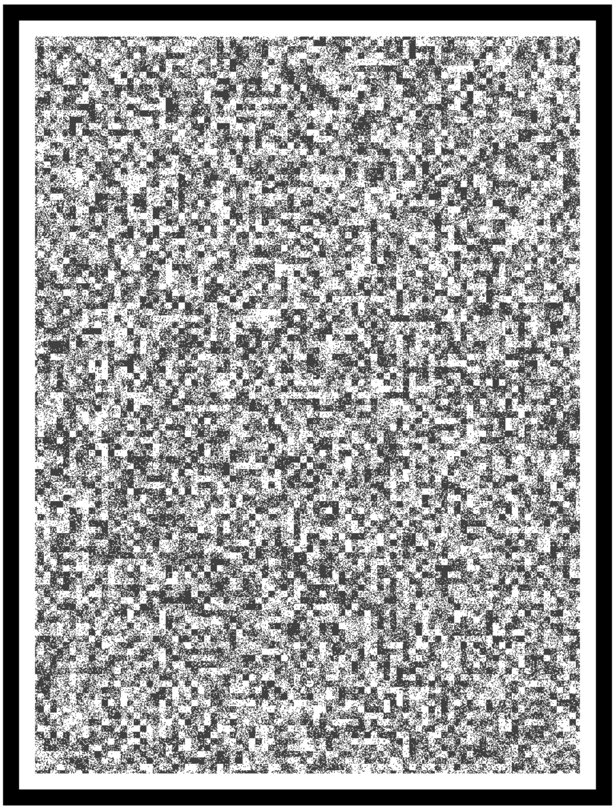

Figure 2: Noise used for depth calibration

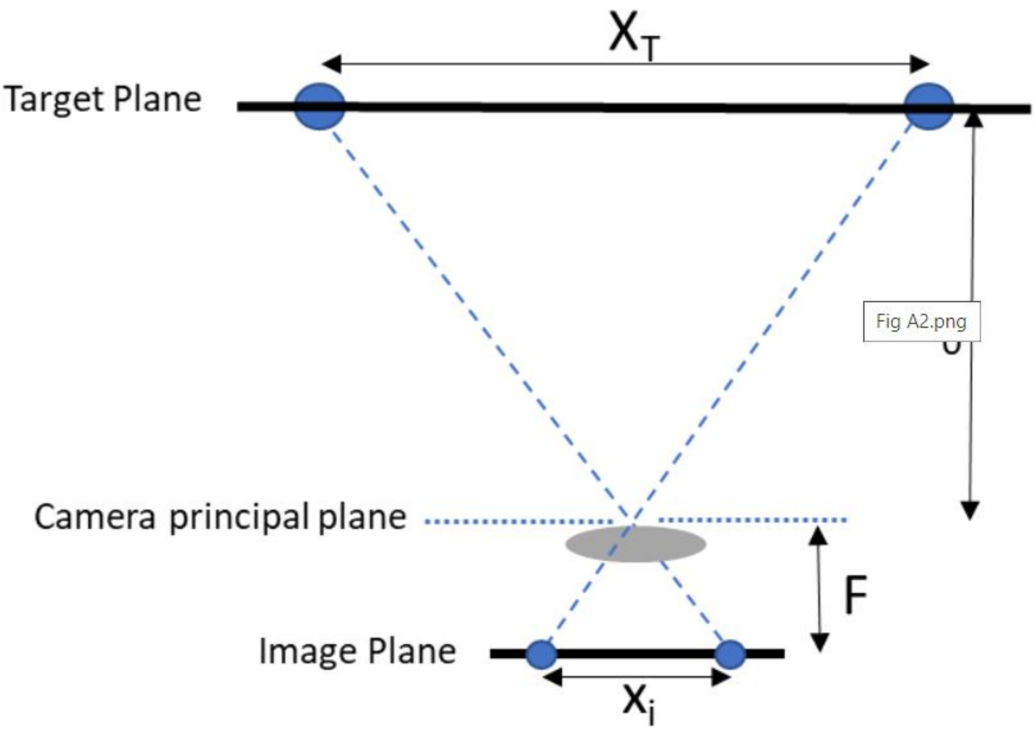

Figure 3: Formula used to obtain accurate ground truth

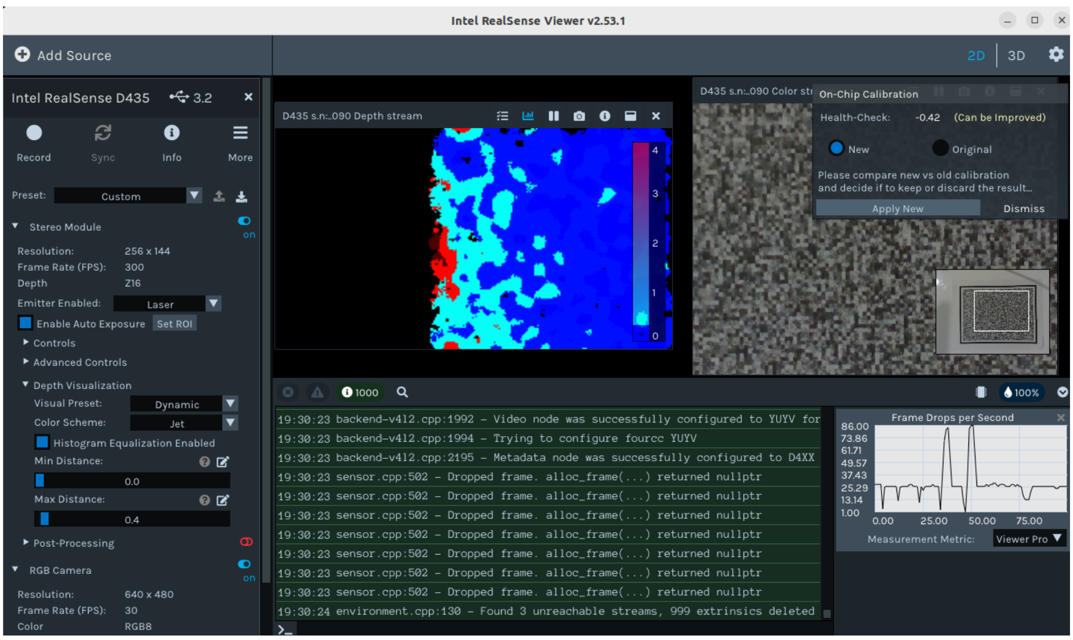

Figure 4: Initial Health score

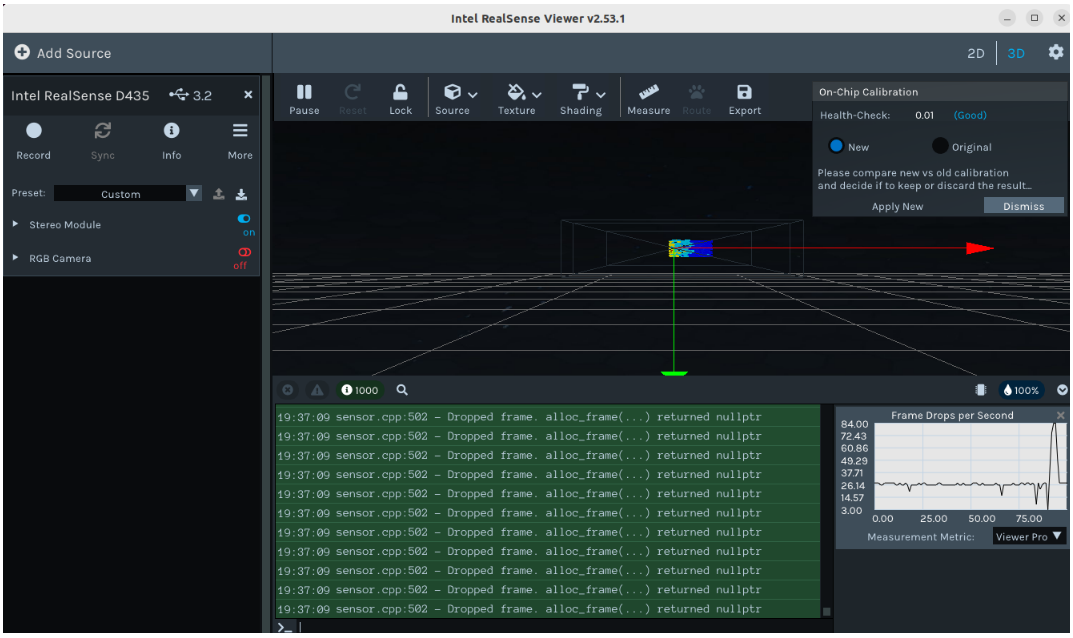

Figure 5: Final Health score

Further, I also worked on the project management end of things. I along with Ronit set up the JIRA board as the team decided to move to JIRA to keep a track on the project progress. I also act as the project owner and am responsible for the sponsor meetings and key deliverable.

2 Challenges

2.1 Infrastructure Manufacturing

Some challenges that we have faced in the manufacturing are as follows. The bolts that we ordered for the 80-20 section were not of the right length and we had to mount the gussets using spacers. We temporarily used washers as spacers but then 3D printed the spacers of the required dimensions. Another issue that we faced was the wrapping of the aluminium plate during welding process. The aluminium plate could not be clamped to the base and the heat caused the aluminium plate to wrap up on itself. Additionally, for testing and calibration we wanted to move the infrastructure down but did not have sufficient length in the 80-20 section. We overcame that challenge by putting another 80-20 below it and attaching the 2 sections together. This made the mounting extremely tedious.

2.2 calibration

We faced various challenges in the calibration of the cameras. The documentation of the camera did not show how calibration is supposed to be. Further, the camera had a problem of frequent disconnection. We tried various methods to solve this problem and finally understood that the problem was in the USB wire and changing it to the new USB 3.2 helped eliminate the issue of frequent disconnects. However we still had no idea about how the calibration of the camera is to be done. We then found some documentation and started the stereo calibration. The calibration of the RGB camera was done using ROS nodes using a 3rd party tool. Ubuntu 22.0.4 however did not support the ROS method we were trying to implement as we were using docker to implement it. We had to finally shift to Ubuntu 20.0.4 to implement the calibration.

3 Team Work

This section talks about the work the team members have been doing in the project.

- **Jash Shah**: Jash worked on the calibration of the RGB camera of the Realsense D435i making the perception and detection of angles of a colored cube more robust and time invariant. he also helped me in manufacturing to make sure we reach the deadlines we have kept for the particular task
- **Shreyas Jha**: Shreyas mainly worked on customization of the RC car and made it remotely operated using ROS nodes. He has been working on understanding how VESC can be integrated on the car.
- **Ronit Hire**: Ronit worked on the PID control and the project management. He also helped Atharv in the control architecture. Further, he set up the JIRA board and developed the backlog page for the team. Ronit has been involved in all domains of the project and also contributed in the calibration of the camera intrinsic and extrinsic.
- **Atharv Pulapaka**: Atharv has been primarily involved in implementing MPC and latency budgets that the other systems can have. He has been working on MPC python simulation of the car.

4 Plans

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

- **My Plans**: I will be validating the camera calibrations starting with the RGB extrinsic using ROS MoveIT and then validate the Stereo Camera calibration using Aruco markers and other calibration methods. This will be followed by replicating the camera calibration and validation at different heights and for all 3 cameras. I also will try to finish the manufacturing of the stands and do the stability test of them in the following weeks. Along with these I will also be working on the project management as the team has moved to JIRA and will be working on this platform moving forward.
- **Team Plans**: The team will be working on various fronts. Firstly, we will try to incorporate tele-operation on the RC car. We will also continue the testing of the PID based control architecture and the MPC based control. Our aim is to ascertain the challenges and merits of each type and choose the one that fits best for our use-case. We will be modeling the controls on our vehicle and test case. We will also try to get the velocity and pose of the vehicle from perception and get the deviation of the car from the center-line.