Automated Driving Using External Perception

Individual Lab Report

MRSD Project Course II

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Team E: OuterSense

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ILR07

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Individual Progress

In the past two weeks, the primary objectives were to integrate the Inertial Measurement Unit (IMU) data into our RC cars, port the VESC IMU module from ROS 2 to ROS Noetic, integrate the VESC odometry package, investigate IMU calibration techniques, explore sensor fusion methods (Madgwick and Mahony), and visualize the relative pose data for sanity checks during integrated testing with Aruco marker-based state estimation that we demonstrated in PR8.

I successfully integrated the IMU data into our system, ensuring that it provides accurate and real-time measurements of vehicle orientation, angular velocity, and linear acceleration in the equivalent ROS message. To maintain compatibility with our existing ROS Noetic-based infrastructure, I undertook the task of porting the VESC IMU module from ROS 2 to ROS Noetic. This involved modifying the codebase to work seamlessly within the ROS Noetic framework, ensuring that it communicated effectively with other components of our autonomous driving system (Vineet Tambe helped me in doing this).

Calibrating the IMU is essential for accurate sensor measurements. I conducted in-depth research on IMU calibration techniques, exploring methods to reduce sensor noise and improve data quality. I further delved into sensor fusion algorithms, specifically Madgwick and Mahony filters, to fuse raw accelerometer and gyroscope measurements form our IMU. This fusion process enhances our system's ability to estimate orientation and position accurately. Investigating different fusion algorithms allowed us to choose the most suitable one for our application. I used the in-built filters in the VESC but it was critical to understand the implementation in order to make trade-offs and tune them effectively. I also integrated the VESC odometry package, which calculates and publishes the vehicle's pose based on data from the ERPM and gains. I dug into the F1Tenth repo and documentation to understand the underlying implementation and in order to tune this.

These are the building blocks towards more robust data association and state estimation - crucial for improving the overall autonomy stack.

During integrated tests, I implemented a visualization tool to display the relative pose data derived from IMU and odometry sources. This visualization aids in sanity checks and provides valuable insights into the performance and consistency of our sensor integration and fusion techniques (a screenshot depicting the translation in each cars local frame is shown below, Fig 1.).

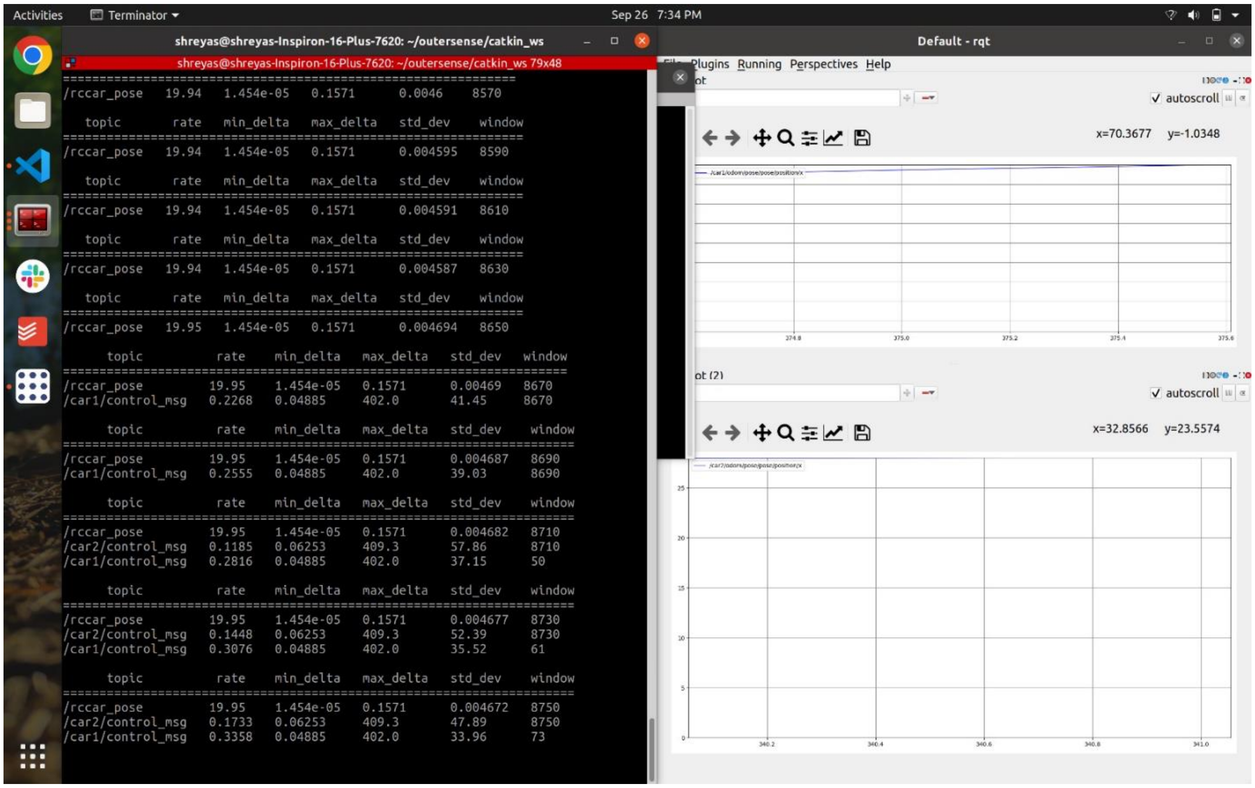

Figure 1: Visualizing odometry feed and pose output rate.

Challenges

ROS 2 to ROS Noetic Porting

The transition from ROS 2 to ROS Noetic presented significant challenges, requiring extensive code modifications and debugging for compatibility.

Teamwork

Atharv Pulapaka: Atharv has continued to explore optimization techniques, both as a joint optimization problem and for individual car stacks. Further integration tests with multiple cars will provide insights into the effectiveness of these optimizations.

Dhanesh Pamnani: Dhanesh's efforts were focused on researching on the planningsub-system for OuterSense. He collaborated with Atharv.

Jash Shah: Jash has undertaken the responsibility of setting up the Gazebo environment for our project. This environment serves as a critical testing ground for planning and decision-making algorithms. His efforts include importing the Ackermann model and customizing it to work seamlessly with our control messages. He also performed integration testing with Atharv.

Ronit Hire: Ronit's work on the Aruco-based multi-object tracker, specifically looking into the implementation of Hungarian matching for data association to maintain stable tracking IDs. He has also been studying approaches to perform the global data association task.

Future Work

I intend to work on the following:

1. **Testing and Validation:** The next phase involves rigorous testing and validation of the integrated system, encompassing real-world and simulated scenarios.

2. **Optimization:** Further optimization of sensor fusion algorithms and IMU calibration will be necessary to fine-tune system performance, especially in challenging environments.

3. **Integration with state estimation stack:** We plan to build a data association and state estimation pipeline fusing multiple sensor modalities (perception, inertial and odometry), using VICON markers as ground truth.

4. **Data Logging and Analysis:** Implementing data logging and analysis tools will be critical for post-test evaluation and system refinement.