

# Automated Driving Using External Perception

Individual Lab Report MRSD Project Course II Fall 2023

Shreyas Jha

Team E: OuterSense

Teammates: Atharv Pulapaka, Dhanesh Pamnani, Jash Shah, Ronit Hire

ILR07

Sep. 28, 2023



# Table of Contents

Table of Contents	2
Individual Progress	3
Challenges	4
Teamwork	4
Atharv Pulapaka	4
Dhanesh Pamnani	4
Jash Shah	4
Ronit Hire	5
Future Work	5

### 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 indepth 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 tradeoffs 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.).

	chrowac	@shreyas-Inspiron	-16-Dlue-762		anso/catkin	ws –	0 🚫				Defe	ult - rat			
-		@shreyas-Inspiron-				THE REAL PROPERTY AND INCOME.		Plugins Ru	nning Per	spectives		uit - iqt			
/rccar pose		1.454e-05 0.					8	ot			_				0
topic		min delta ma		std dev	window						4 <b></b>				✓ autoscro
/rccar pose			1571	0.004595				< →	<b>+</b> Q ≣		)			x=70.3	677 y=-1.034
topic				std dev	window			- /car1/odom/por	erpose/position/x						
/rccar_pose		=======================================	1571	0.004591	=========			_							
topic		min delta ma		std dev	window						_				
======================================			1571		8630										
topic				std dev	window										
/rccar_pose			1571	0.004694											
topic			ta max d			window			274.8		375.0	3	75.2	375 A	
/rccar_pose		.95 1.454e-	05 0.157	71 0	.00469	8670		ot (2)							√ autoscro
/rccar_pose /car1/control	19 _msg 0.	.95 1.454e- 2268 0.04885	05 0.15 402.0	71 0 9 4	.00469 1.45	8670 8670					4 <b></b>				✓ autoscro
/rccar_pose /car1/control topic	19 msg 0. r	0.95 1.454e- 2268 0.04885 ate min_del	05 0.157 402.0	71 0 9 4 delta s	.00469 1.45 td_dev =========	8670 8670 window			+ Q ≇					x=32.85	
/rccar_pose /car1/control topic	19 msg 0.   19	0.95 1.454e- 2268 0.04885 ate min_del	05 0.157 402.0 ta max_0	71 0 9 4 delta s 71 0	.00469 1.45	8670 8670 window				e 🗠 🖪				x=32.85	✓ autoscro
/rccar_pose /car1/control topic 	19 msg 0.  msg 0. r	0.95 1.454e- 2268 0.04885 ate min_del .95 1.454e- 2555 0.04885 ate min_del	05 0.157 402.0 ta max_0 05 0.157 402.0 ta max_0	71 0 9 4 delta s 71 0 9 3 delta s	.00469 1.45 td_dev ======== .004687 9.03 td_dev	8670 8670 ******* 8690 8690 window	25 -	<b>*                                    </b>		e 🗠 B				x=32.85	✓ autoscro
/rccar_pose /car1/control topic /rccar_pose /car1/control topic /rccar_pose	19 msg 0.  msg 0.   19  19	0.95 1.454e- 2268 0.04885 ate min_del 0.95 1.454e- 2555 0.04885 ate min_del .95 1.454e-	05 0.157 402.0 ta max_c 05 0.157 5 402.0 ta max_c 05 0.157	71 0 9 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	.00469 1.45 td_dev .004687 9.03 td_dev .004682	8670 8670 window 8690 8690 window 8710	25 -	<b>*                                    </b>		≡⊿ 8				x=32.85	✓ autoscro
/rccar_pose /car1/control topic /rccar_pose /car1/control topic	19 msg 0. r  msg 0. r  19 msg 0.	0.95 1.454e- 2268 0.04885 ate min_del 0.95 1.454e- 2555 0.04885 ate min_del	05 0.157 402.0 .ta max 05 0.157 402.0 .ta max 05 0.157 409.1 409.1	71 0 9 4 delta s 71 0 9 3 delta s ========= 71 0 3 5	.00469 1.45 td_dev .004687 9.03 td_dev	8670 8670 ******* 8690 8690 window	25 -	<b>*                                    </b>		≡ <b>∠</b>				x=32.85	✓ autoscro
/rccar_pose /cari/control topic /rccar_pose /cari/control topic /car2/control /cari/control topic	19 msg 0. msg 0. msg 0. msg 0. msg 0. msg 0.	9.95 1.454e   2268 0.04885   vate min_del   9.95 1.454e   2255 0.04885   vate min_del   9.95 1.454e   255 0.04885   vate min_del   1.95 1.454e   1.95 1.454e   1.95 1.454e   2816 0.04885   vate min_del	05 0.157 402.6 ta max_c 05 0.157 402.6 ta max_c 05 0.157 402.6 409.2 409.2 ta max_c	71 0 9 4: delta s: ========= 71 0 9 3: delta s: ======= 59 3: delta s:	.00469 1.45 td_dev .004687 9.03 td_dev .004682 7.86 7.15 td_dev	8670 8670 	25 20 23	<b>*                                    </b>		2 <b>~</b> 8				x=32.85	✓ autoscro
/rccar_pose /cari/control topic /rccar_pose /cari/control /rccar_pose /cari/control /cari/control topic	19 msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 19	.95 1.454e   .2268 0.04885   ate min_del   .95 1.454e   .2555 0.04885   ate min_del   .95 1.454e   .2555 0.04885   ate min_del   .95 1.454e   .95 1.454e   .95 1.454e   .95 1.454e   .95 1.454e	05 0.157 402.6 .ta max_ 05 0.157 402.6 .ta max_ 05 0.157 409.2 409.2 409.2 409.6	71 0 9 4 delta s 71 0 9 3 delta s 71 0 3 5 9 3 delta s 5 9 3 delta s 71 0 71	.00469 1.45 td_dev .004687 9.03 td_dev .004682 7.86 7.15 td_dev .004682 7.15	8670 8670 window 8690 8690 window 8710 8710 50 window 8730		<b>*                                    </b>						x=32.85	✓ autoscro
/rccar_pose /cari/control topic /rccar_pose /cari/control topic /rccar_pose /car2/control /cari/control	19 msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 0.	.95 1.454e   2268 0.04893   ate min_del   .95 1.454e   2255 0.04885   ate min_del   .95 1.454e   2255 0.04885   ate min_del   .95 1.454e   2255 0.04885   ate min_del   .95 1.454e   .96 .96253   .96 .964885	05 0.157 402.6 402.6 05 0.157 402.6 402.6 402.6 402.6 402.6 402.6 402.6 402.6 402.6 402.6 402.6	71 0 delta s 71 0 0 3 delta s 71 0 3 5 3 71 0 delta s 71 0 3 5 7 0 3 5 7 0 3 5 7 0 0 3 5 0 3 5 0 3 5 0 3 5 0 3 5 0 3 5 0 3 5 0 3 5 0 3 5 0 3 5 0 3 5 0 3 5 5 0 3 5 5 0 3 5 5 0 3 5 5 0 3 5 5 0 3 5 5 0 3 5 5 5 5 5 5 5 5 5 5 5 5 5	.00469 1.45 td_dev .004687 9.03 td_dev .004682 7.86 7.15 td_dev	8670 8670 		<b>*                                    </b>		≡ ⊻ 8				x=32.85	✓ autoscro
/rccar_pose /carl/control /rccar_pose /carl/control /rccar_pose /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control	19 msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 0.	.95 1.454e.   2268 0.0488'   ate min_del   .95 1.454e.   2555 0.0488'   ate min_del   .95 1.454e.   255 0.0488'   2816 0.0423'   2816 0.0488'   ate min_del   .95 1.454e.	05 0.15; 402.6 402.6 402.6 402.6 402.6 402.6 402.6 409.3 409.3 409.3 409.3 409.3 409.3 409.3 409.3 409.6 402.6 40.6 40.6 40.6 40.6 40.6 40.6 40.6 40.6 40.6 40.6 40	71 0 delta s: 71 0 3 3 delta s: 71 0 3 5 3 5 3 5 3 5 3 3 delta s: 3 5 3 3 delta s: 3 5 3 3 delta s: 3 4 delta s: 3 3 delta s: delta s: del	.00469 1.45 td_dev 004687 9.03 td_dev .004682 7.86 7.15 td_dev .004677 2.39 5.52 td_dev	8670 8670 8670 8690 8690 8710 8710 50 window 8710 50 window 61 window		<b>*                                    </b>						x=32.85	✓ autoscro
/rccar_pose /carl/control rccar_pose /carl/control /rccar_pose /carl/control /rccar_pose /car2/control /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control /carl/control	19 msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 0. msg 0.	.95 1.454e   .2268 0.04885   ate min_del   .95 1.454e   .2555 0.04885   ate min_del   .95 1.454e   .185 0.04855   .2816 0.04885   .95 1.454e   .185 0.06253   .2816 0.04835   .95 1.454e   .148 0.06253   .9676 0.04885	05 0.15; 402.6 402.6 402.6 402.6 402.6 402.6 402.6 402.6 402.6 402.6 409.3 409.3 409.3 409.3 409.3 409.3 409.3 409.2 409.6 400.6	71 0 delta s: 71 0 3 delta s: 71 0 3 3 5 3 4 6 1 3 5 3 3 5 3 3 5 3 3 5 3 3 5 3 3 5 3 3 5 3 3 5 3 3 5 3 5 3 5 3 5 5 3 5 5 5 5 5 5 5 5 5 5 5 5 5	.00469 1.45 td_dev 004687 9.03 td_dev .004682 7.86 7.15 td_dev .004677 2.39 5.52 td_dev	8670 8670 8670 8690 8690 8710 8710 50 window 8710 50 window 61 window		<b>*                                    </b>						x=32.85	✓ autoscro

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 planningsubsystem 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.