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EECE 404: Senior Design

100/100

Spring 2025

Autonomous Vehicle Communication Project

By

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In Collaboration with Quanser
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Project Summary

This project in the Autonomous Vehicle Robotics and Control Laboratory focuses on developing a leader-follower system between an autonomous ground robot and an aerial vehicle. The project utilizes Quanser's QBot 2, an autonomous ground robot, as the leader and the QDrone, an air vehicle, as the follower. The objective is to establish vehicle-to-vehicle communication, where the QBot 2 sends its location coordinates to the QDrone, which follows the leader by determining the appropriate trajectory to take. This project was done over the course of two semesters with the first focus being on theory and then implementation. One of the first steps was to establish the need of the leader-follower system and from that derive a problem statement. Next, the design requirements for this leader-follower system were noted. The technical specification for the overall project and its different constraints were all gathered: socio-cultural, environmental, and compliance. The ideas and concepts on how the leader-follower system should behave was drawn in a patent format. In the second semester, the focus was on implementation. The project was divided into three main sprints and weekly goals were made.

Problem Statement

Search and rescue operations are crucial during and after armed conflicts to locate and assist the injured. QBot operates as the leader and sends its coordinates in real time and the optimal path is determined. The location of the injured is sent to the ground station and the QDrone is also able to deliver a package of basic supplies to the recipient.

Design Requirement (QDrone 2)

QDRONE 2		
Requirements	**Items**	**Quantity**
1. **Product (or Software) Specification**	Dimensions	50 x 50 x 15 cm
	Weight (with batteries)	~ 1500 g
	Max Payload	~ 300 g
	Power	4S 14.8V LiPo (3700mAh) with XT60 connector
	Flight Time	7-8 minutes for hover per battery charge
	Onboard Computer	NVIDIA Jetson Xavier NX SOM (powered by a 6-Core NVIDIA Carmel ARM v8.2 64 Bit processor)
	Intel® RealSense™ ((D435)	Depth sensing: (3 metre range) RGB (1920X1080) @ 30 FPS)
	Omnivision OV9281	Grayscale (1280×800 @ 120 FPS or 640×480 @ 180 FPS)
	Sony IMX219	3x RGB CSI 160 deg FOV wide angle lenses Cameras providing side and back view 21 FPS to 120 FPS
	On board sensors	2x 6-DOF IMU (gyroscope and accelerometer), 1x Optical Flow sensor, 1x ToF height sensor
	Connectivity	WiFi 802.11a/b/g/n/ac 867Mbps with dual antennas 1x Micro HDMI port for external monitor support
	Supported Software and APIs	QUARC for Simulink, Quanser APIs, TensorFlow, TensorRT, Python 2.7 & 3, ROS 1 & 2, CUDA, cuDNN, OpenCV, Deep Stream SDK,

		VisionWorks, VPI, GStreamer
2. Constraints	Environmental Constraints	-Drone has to be flown in a limited space -Noise Limit: Drone cannot exceed 85dB noise limit -Drone Speed: A maximum of 100 miles per hour (87 knots)
	Socio-Cultural Constraints	Privacy Sensitivity
	Compliance (Rules, Regulations, and Standards)	-7m by 7m nets must be mounted in test space for safety of people and equipment -6 cameras must be set up for monitoring and indoor tracking of QDrones

Design Requirement (QBot)

QBOT		
Requirements	**Items**	**Quantity**
3. Product (or Software) Specification	Platform	2-wheel differential drive base with 4 support castors
	Diameter	570 mm
	Height	227 mm
	Drivetrain sensing	Current sensing, optical encoders, and digital tachometer per wheel
	Maximum motion	1.5 m/s speed and 1 m/s/s acceleration
	Nominal motion	0.7 m/s speed and 0.5 m/s/s acceleration
	Maximum payload @ maximum motion	20 kg
	Operation time	2 hours per battery
	Power	Up to 2x 84Wh LFP batteries w/ external charging
	Onboard computer	NVIDIA Jetson Orin Nano
	Downward facing camera	Grayscale w/ global shutter – 640×400 @ 120Hz
	Front facing camera	Intel RealSense D435 RGB-D camera
	LiDAR	2D 360° lidar w/ 16,800 points per second
	Connectivity	IEEE 802.11ac Wi-Fi & Gigabit Ethernet port

Solution Design (Fall 2024)

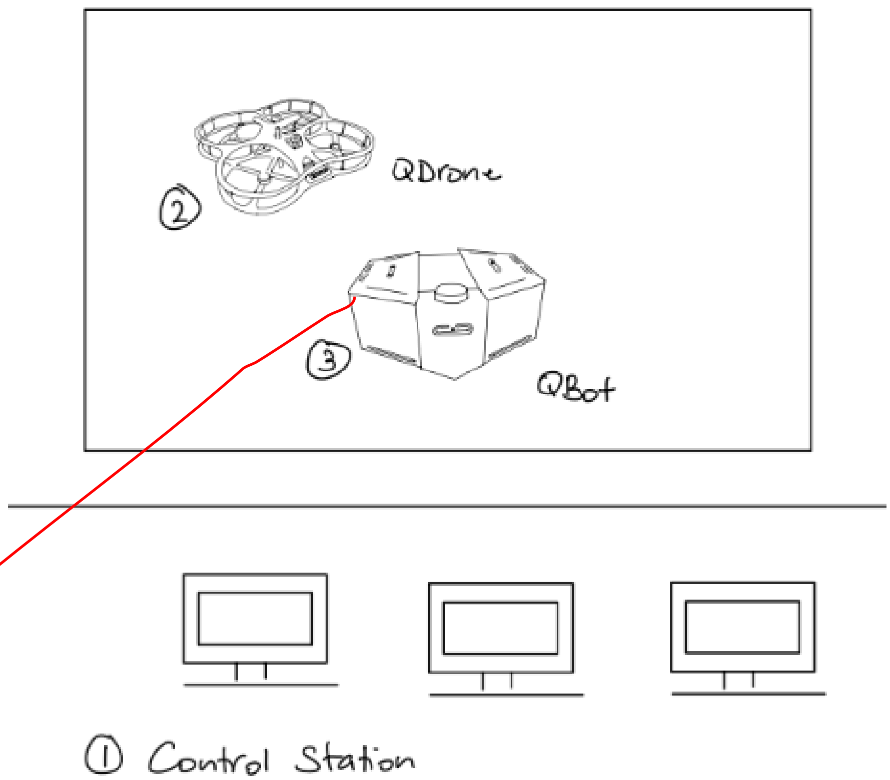

Fig1- Sketch showing Set Up for ground station (Resources: Quanser)

QDrone (2) and Qbot(3) are set up in an enclosed space, and are wirelessly connected to Ground control station (1). Control algorithms are uploaded using the QUARC Real-time Control software and then deployed to the Qbot and Qdrone. The data gathered by the Qbot and Qdrone 2 are sent to the QUARC software and monitored by the control station in real-time.

Project Implementation (Spring 2025)

Agile Workflow and Weekly Plan

Starting Date of Week (M)	**Sprint #**	**Increment (or intermediate working component)**	**Weekly development tasks**
1/27/2024	1	QUARC setup success	Installing and setting up QUARC
2/3/2024			Testing MATLAB/Simulink & QUARC Primer
2/10/2024			Perform Software-Only Test and DAQ Test
2/17/2024	2	Completed model Configurations	Design Localization and State Estimation Model
2/24/2024			Design model for mission control
3/3/2024			Spring Break
3/10/2024			Design model for flight commands
3/17/2024	3	Autonomous vehicle communication between Qbot and Qdrone	Setting up hardware and testing
3/24/2024			Testing of autonomous vehicles communication model
3/31/2024			Testing of autonomous vehicles communication model contd.

Project Implementation Process (Spring 2025)

Sprint 1

Below are the planned tasks for the first sprint of the project:

- Obtaining license for QUARC software; setting up QUARC
- Matlab & Simulink Training for each team member
- Running Software Tests
- Setting up subsystems in Input and Output model

Increment: Setting up IO (Input Output) model on Matlab for the QBot

For the highlights of this sprint, the model was able to connect and process data from external input, which was an external camera connected to the working laptop, successfully. Also different subsystems created for the IO model by each team member.

Lowlights: Equipment and software did not arrive on the estimated time of delivery. A lot of computer memory was required to run the QUARC (Quanser Real Time Control) application which made it difficult for the models to run smoothly. Not every member was able to download software on his laptop. Lastly, there was no in-person training for QUARC software. The pictures below show the different subsystems of the Qbot Hardware, set up in the Matlab Simulink environment.

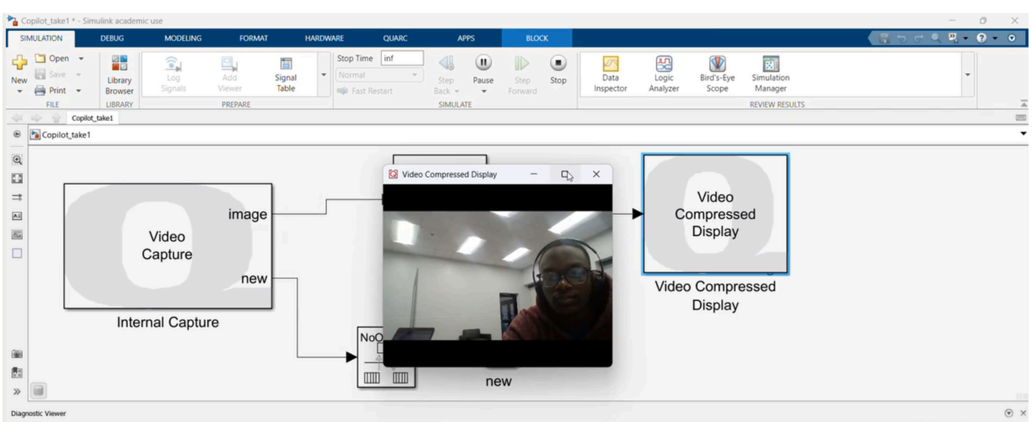

Fig 2 - External camera (laptop) connected to test basic IO model

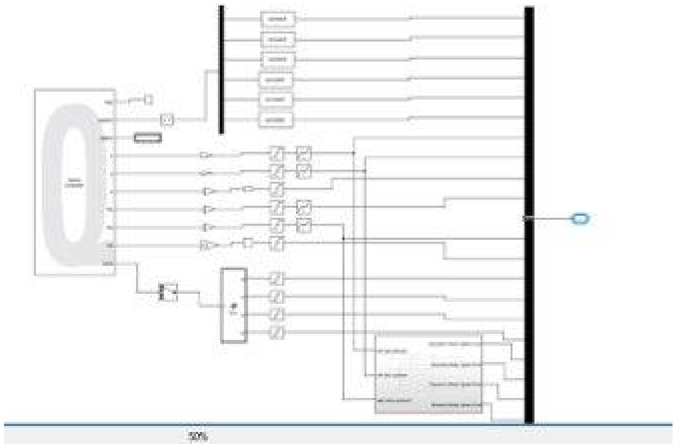

Fig 3- Joystick Driver Model

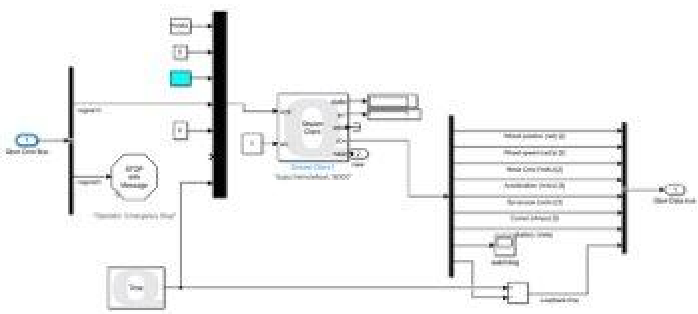

Fig 4- QBot Hardware

Resolution to Challenges

At the time, the failure risk was assessed as medium due to potential equipment delays and the absence of in-person software training. Lack of in-person training on Quanser software. To mitigate the risk of delays due to hardware not arriving on time, an alternative strategy was utilized, a virtual platform for remote testing. Additionally, to address the lack of in-person training on Quanser software, establishing regular remote meetings with Quanser representatives was done to provide the necessary guidance and support.

Sprint 2

Below are the planned tasks for the second sprint of the project:

- Obtained license for QLabs Virtual Environment.
- Implemented MATLAB scripts and Simulink models in the Qlabs virtual environment.
- Forward and reverse motion of virtual Qbot.
- Data monitoring and analysis of virtual Qbot.

Increment: Virtual Qbot set up, testing, and analysis.

For the highlights of this sprint, the QBot movements were modeled in the Qlabs Virtual Environment. Also Qbot data was monitored and analyzed using Simulink models simultaneously in the MATLAB and Qlabs environment.

Lowlights:

- The Physical Equipment was not set up at that time in the Lab Space.
- Limitations with model testing in Virtual Space
- QLabs frequently crashing due to low processing power on laptop

The pictures below show the data for wheel speeds, forward velocity and turn velocity of the Qbot Hardware, as it was being controlled in the Qlabs environment virtually.

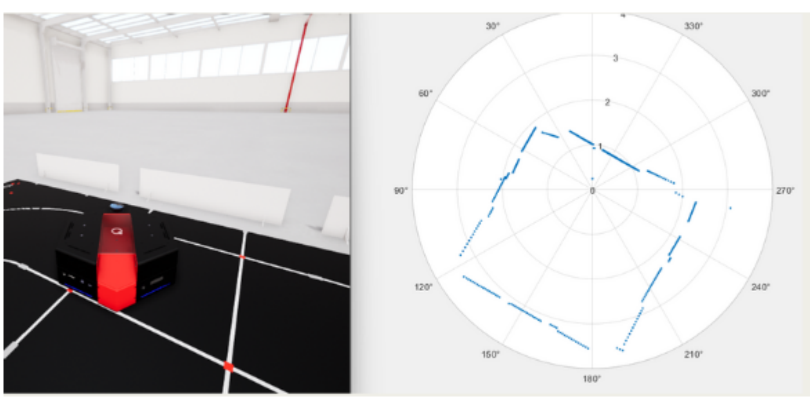

Fig 5- Creating map of virtual environment for Qbot's localization

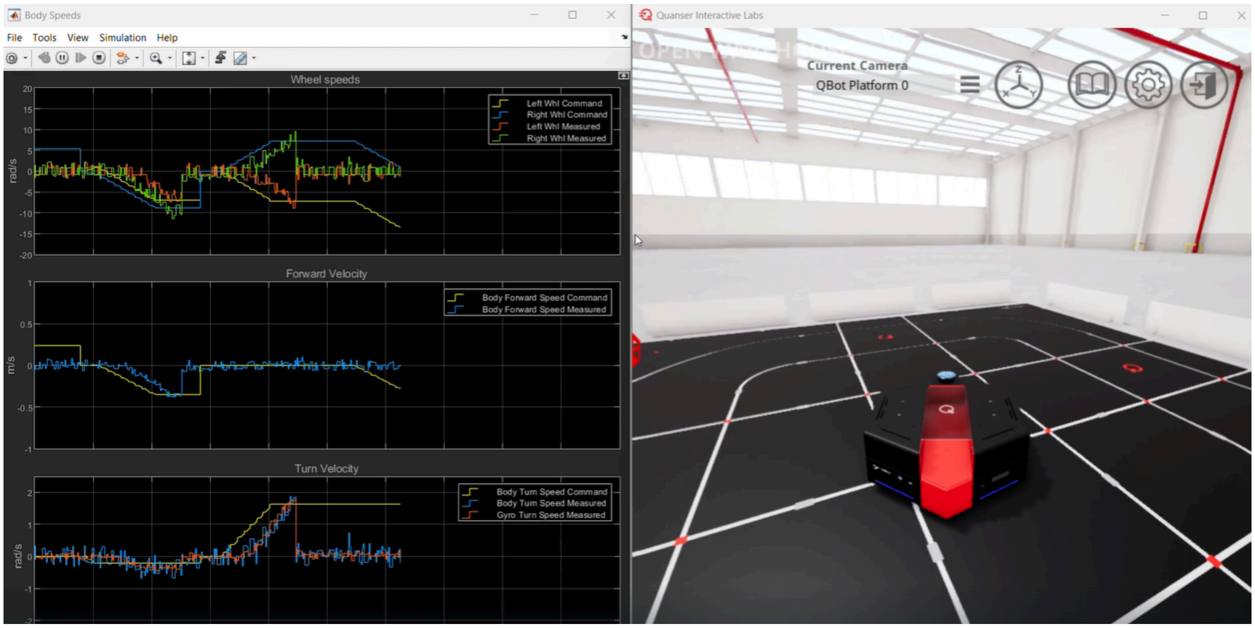

Fig 6- Wheel Speeds, Forward Velocity and Turn Velocity recorded during Qbot testing

Resolution to Challenges

At the time, the failure risk was assessed as medium due to difficulty in setting up hardware components due to time constraints and testing space, and limitations in testing autonomous vehicles in the virtual environment. To mitigate those challenges we proposed the idea of using a single Qdrone and Qbot platform in an open space, and also working with Quanser representatives to help increase functionality.

Sprint 3

Below were the planned tasks for the third sprint of the project:

- Implemented Mission Server and Commander Stabilizer Simulink Models
- Established communication between Qdrone and Qbot in virtual environment
- Set up and monitored data for physical Qbots
- Drone camera tests

Increment: Established the leader-follower communication between Qdrone and Qbot in the Qlabs virtual environment. Unfortunately due to the lack of a lab space, the required 7m by 7m space for the drone setup was not available. Therefore the drones were not flown, but only camera tests were performed on them.

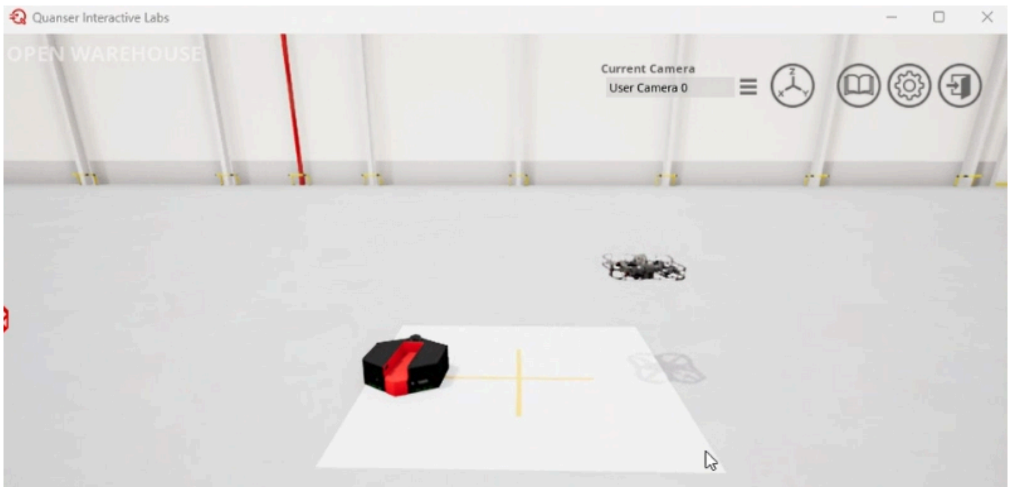

Fig 6- Leader-follower system in QLabs

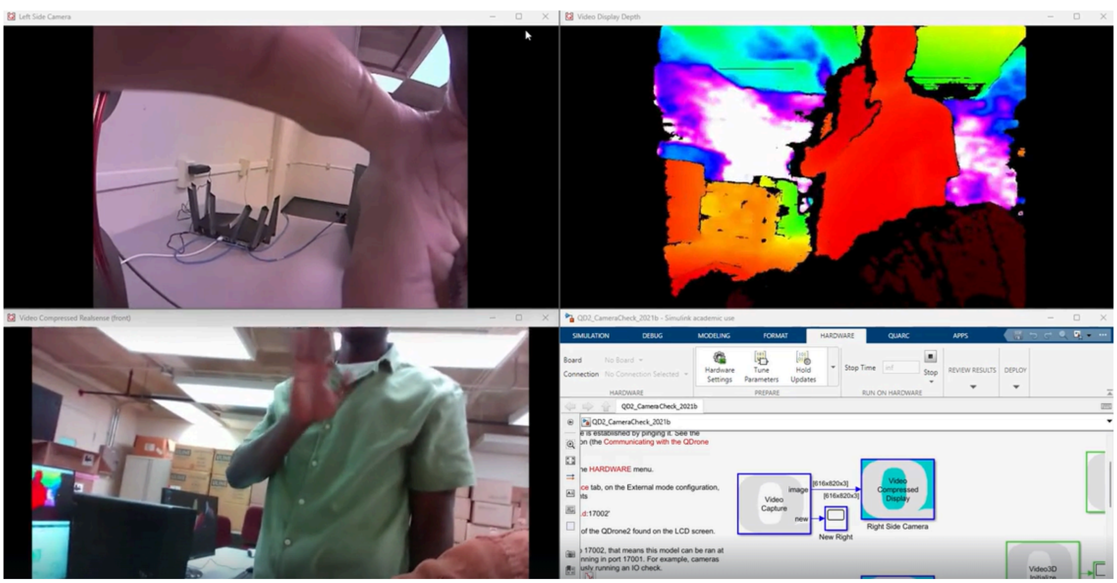

Fig 7- Drone Camera Testing (Depth camera- top right)

Other pictures from our project implementation

Fig 7- Setting up the necessary floor padding

Fig 8- Charging drone battery

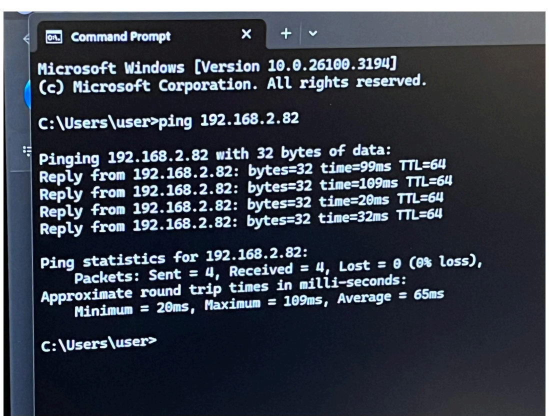

Fig 9- Pinging Qbot (connecting to ground station)

Fig 10- Two Qbots

Conclusion

In this project, we implemented a leader-follower communication system for autonomous vehicle communication. By following a thorough process of planning with project constraints taken into account, research into key concepts such as wireless communication, autonomous vehicle navigation and control systems, followed by concept design and implementation, we were able to successfully establish communication between a ground station, an unmanned ground vehicle and an unmanned aerial vehicle. This project helped further our understanding of robotics and wireless communication as well as giving us insight into industry processes.

References

- Quanser Academic Resources (https://www.quanser.com)
- Simulink Onramp Mathworks (https://matlabacademy.mathworks.com/details/simulink-onramp/simulink)
- Senior Design Class Lecture Notes (Dr Charles Kim)
- Introduction to AI Robotics - Murphy R.R
- The Robotics Primer - M. Mataric