ECED 3901: Assignment 2

Date: January 21, 2026

Due: February 04, 2026

Learning Outcomes:

The purpose of this assignment is to have you create an architecture diagram. To do this effectively, we must understand the source and degree of uncertainty in your robot's pose estimates, from odometry and from the ranging sensor. Your first design task was to perform dead-reckoning of a shape and you may notice it is very challenging to return to the same spot. Knowledge gained will provide necessary information for your design solution to the final challenge.

Deliverables:

1. Answer the questions below (max. 5-pages). Each question is equally weighted and relates the robot technical capabilities and limitations to the design process (100%).

Submit one document with your team's assignment solutions. The work must be **your team's own original thoughts and answers**. Copying will not be permitted and will result in zero points for the entire team for the assignment.

Question 1:

Draw 2 initial design architecture block diagrams for your system, one for electrical and one for firmware/software.

Hint: at the resolution of technology function blocks, what hardware and software elements are required on the robot to meet the client's requirements? Power, Motion, Navigation, Object Detection, Metal sensors, Lights, Arms, Grippers, Shovels, etc.

Explain in one or two sentences the purpose of each functional block. Describe how sub-elements connect to other aspects of the system and what is exchanged at interfaces.

Do reading on technology readiness levels (TRLs) and assign a TRL to each element. Which of these elements do you anticipate will require the most innovation, testing, and refinement? Why?

Question 2:

Understanding and quantifying uncertainty is critical when reporting the robot pose. In our case, the pose represents the vehicle location (X, Y) and the orientation (Θ) on the map.

a) What is odometry? Why does it matter for pose estimation? Which of the client's requirements does it help you satisfy?

b) What is the difference between systematic and random errors?

c) What is the difference between error and uncertainty?

d) When the robot formulates an estimate of X, Y and Θ, what events/instances/cases/operations would contribute to the overall uncertainty (±eX, ±eY and ±eΘ)? Does the Gazebo simulator capture these? What does it not cover?

Question 3:

Odometry clearly has utility and limitations. As such, we often include other sensors on a robot for localization including sonars, LiDARs, Radars, GPS, etc.

a) What are proprioceptive sensors, exteroceptive sensors and interoceptive sensors?

b) Can you give examples of each of these types of sensors?

c) Do you have any of these sensors on the design challenge robot? Are you missing any such sensors that could improve the likelihood of success?

Question 4:

Getting down to specific hardware matters. Your remote robots are equipped with wheel encoders, an inertial measurement unit (IMU), and a LiDAR.

a) How will the encoder system be used in your robot's design? What are the specifications of the encoders? How does quadrature signal encoding work?

b) How will the LiDAR be used in your robot's design? What are the specifications of the LiDAR? Please explain the operating principles of "phase-shift" and "time-of-flight" and "triangulation" LiDARs. How does the unit on your robot measure range data?

c) Which client requirements can be satisfied by these two sensors? What else is required to augment these sensors to fully complete the client requirements?

Question 5:

Here we will investigate, analyze, and interpret data from the IMU to understand the potential uncertainty it adds to our pose estimation.

a) Create a template that allows observation of angular accuracy. Photo the template and comment on the dimensional accuracy of your template.

b) Place your robot on the template.

c) Start the IMU drivers using ROS2 and capture data for 5-10 seconds. Plot the data and show the graph of relevant data points. It is suggested that you plot angular velocity versus time.

d) Make a quantitative statement on the uncertainty of the angular velocity and compare it to the datasheet. Is it within specification?

e) Rotate the robot on the spot using the teleoperation package to a new angle, after completing 2-3 full turns.

f) What is the difference between the expected angle and the actual angle (yaw)? Take a photo as supporting evidence. Explain the difference, and will the IMU be sufficient for your challenge?