Lab 1 – Sensor Modelling

Goals:

- Model sensor output of an infrared (IR) distance sensor over a set of distances
- Characterize sensor uncertainty using a probability distribution
- Compare sensor operation to the sensor datasheet

Description

In this lab you will apply the techniques learned in class to properly model and characterize a set of infrared (IR) sensors. You will be given 3+1 IR sensors to work with; The 3 sensors include 1 short-, 1 medium- and 1 long-distance sensor. In addition, you have your choice of one duplicate sensor to work with. From the datasheets posted on UW-Learn, determine appropriate output measurement ranges and sample rates (from the timing chart listed on the datasheet) that you will be using.

Data analysis can be performed using your preferred tool (MATLAB, Python, Excel, etc.) However, your analysis should be properly accompanied with the corresponding calculations used to develop your program. Please note, the model that you develop in this lab will be used for future labs. In order to be confident about your mode, test your model properly and describe that in your report.

Answers to questions in the lab report should be kept brief and can use sentences, point form, equations, and/or sketches (take a clear photo to include in the document) where appropriate. Don't forget that every figure should have a figure number, and a caption.

In-Lab Activity

Setup

You will be modelling the Sharp IR distance sensor using a cube of aluminum, a meter stick and the NI ELVIS II+ data acquistion board. The sensors connect to the ELVIS Board as follows

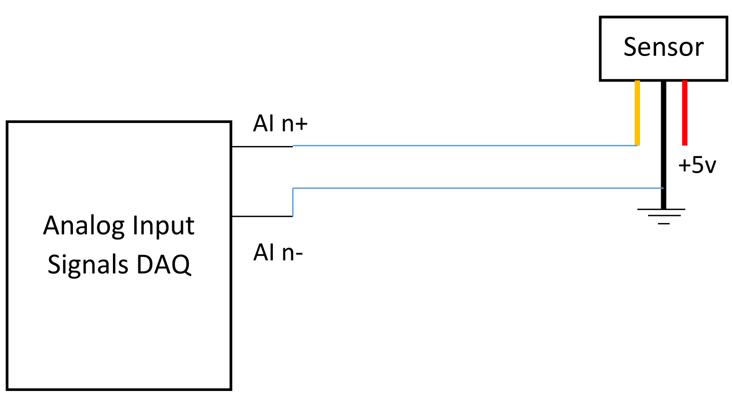

Figure 1 Sensor pinout and its connection to DAQ board using a JST connector cable. The red, black, and yellow wires of the cable are connected to the +5v, ground, and the output pins of the sensor.

Ensure that you have the corresponding sampling rate for the appropriate sensor.

Adjust the height accordingly for each of the sensors on the sensor mounts.

You can collect the data using the MATLAB script provided on UW-Learn. If you make changes to the script to facilitate data collection, save the script, as you will use it again in Lab 2.

Data collection

Part A: Sensor Model

For each of the 3 types of sensors (short-, medium- and long-distance) collect data by:

1. Placing the sensor at a distance representing the closest position for its operating range as given in the sensor's datasheet.
2. Recording a set of measurement samples of the output voltage.
3. Moving the sensor further away and repeating the process.

Your measurements sample set should cover the entire operating range of the sensor (e.g., For the medium distance sensor: 10 cm, 20 cm, …, 80 cm).

After you have collected the data, for each of the three sensors:

1. For each set of measurement samples (i.e. each distance measurement) determine the mean output voltage of the measurement set.
2. Plot distance vs. mean output voltage for the sensor.

Verify that the output voltage measurements change monotonically as the distance increases. Retake any measurements where this is not the case.

Part B: Two Sensors

Set up your system so that it has two sensors (of different types or the same type) that provide competitive distance measurements. Collect measurement samples from both sensors at 5 different distances.

1. Provide a photo of the measurement setup.

Part C: Different Sampling Rates

Collect sensor measurement data for a higher sampling rate (e.g. 10X higher, i.e., at each 1 ms rather than each 10 ms).

Part D: Other Conditions

Collect sensor measurement data under at least two "other" conditions such as:

- Different reflective material
- With slightly tilted "Block"

Post-Lab Activity

Part A: Sensor Modelling

After you have collected the data, for each of the three sensors:

1. For each set of measurement samples (i.e. each distance measurement) determine the mean output voltage of the measurement set.
2. Provide a plot of distance vs. mean output voltage for the sensor.
3. Fit an appropriate function f to this data to determine the equation for the sensor model.

$$voltage = f(distance) \qquad \text{(eq1)}$$

4. Compare the values produced by the equation with the corresponding mean output voltages.
    a. State the maximum error (difference) and the average error.
    b. Is it reasonable to assume zero-mean Gaussian noise to model the error?
5. Compare the plot and line/curve fit to the information in the datasheet,
    a. Describe the similarities and differences.
    b. What is the maximum voltage difference between the two?
    c. State at least one possible cause for the differences between the sensor operation given in the datasheet and your measurements.
6. For each set of measurement samples (i.e. each distance measurement) for a given sensor
    a. Plot the histogram of the measurement samples.
    b. Fit a Normal (Gaussian) distribution to the measurement sample data; Comment on any outliers and how they affect the distribution.
    c. State the standard deviation and variance for the measurement set at each fixed distance.
7. Compare the histograms and Normal distributions for all the sets of measurement samples for a given sensor:
    a. Are the histograms similar in shape? For any that are significantly different, give a reason why they might be different.
    b. Are the variances similar?
    c. If one variance is to be used for modelling the sensor over its entire range of operation, what is a reasonable variance to use? Why?
8. State the sensor model equation given additive Gaussian noise:

$$voltage = f(distance) + \eta \quad \text{where } \eta \sim \mathcal{N}(0, \sigma^2) \qquad \text{(eq2)}$$

9. Compute the inverse equation

$$distance = g(voltage) \qquad \text{(eq3)}$$

Part B: Two Sensors

For the measurements at each distance:

1. Use the sensor model from Part A for the corresponding sensor types to convert the measurements to **distance measurements.**
2. How do the distance measurements compare between:
    a. The two sensors
    b. Sensor 1 and the ruler distance

   c. Sensor 2 and the ruler distance
   d. The average of the two sensors and the ruler distance

   Comment on the results obtained.

3. For any larger than expected errors, state why the sensor may have performed poorly.

Part C: Different Sample Rates

For the measurements at different sample rates:

1. Did the change in sample rate have an impact on the sensor measurements?
2. Looking at the sensor measurements over time, is there a pattern to the error (periodic pattern or error as a function of distance) or does it resemble white noise? If there is a pattern, does changing the sample rate have an impact?

Part D: Other Conditions

When operating under "other" conditions:

1. Describe how you changed the measurement setup (include a photo or sketch if needed)
2. What was the impact of the change in conditions on the performance of the sensor? Was this what was expected given how the sensor operates?

Report

Submit the report file with answers to the questions, plots, simulation files, and photos to the Dropbox on UW-Learn.