ECEC-T580: Computing and Controls, Fall 2018-19
Project 3 Rev 0

Objective: To implement a Kalman filter to estimate the position (and velocity) of a 'particle' using an ultrasonic transduce as the measurement. In order to do this your team will need to determine the statistical properties of the ultrasonic transducer and then simulate the position versus time curve of the particle by taking a series of measurements obtaining both ground truth (measured by a ruler or tape measure) and sensor measurement.

Discussion:

1) **Obtaining the statistics of the Ultrasonic Transducer.**

Refer to the document: **Ultrasonic_Sensor.docx** which discusses the connections and shows some waveforms for ultrasonic sensor available at the 2nd floor parts window. It also has a reference for addressing the temperature and humidity which can change sensor readings.

a) You should try to find more data/specifications for these sensors if possible, such as some kind of accuracy specification.
b) **Analog measurement of uncertainty.** It is suggested that before connecting to the microcontroller you use a signal generator to create pulses (correct duration and spacing) and look at the echo pulse. Use a good target and make sure the sensor is well supported. Measure the distance from the front face to the target. If you trigger the scope on the rising edge of the echo pulse the trailing edge should dither in time. This dither is an indication of the error in measurement. You may have to increase the sweep rate and note the location corresponding to multiple measurements manually – you may be able to set the scope to record the changes or obtain data from scope (as done in Dr. Peter's course). The scope may have a persistence setting that allows traces to overlay one another.
    - Try this for a few different distances, say 6, 12, 18 and 24 inches – make accurate measurements by hand.
    - Try for at least 3 different sensors (mark sensors or use serial number to identify)
    - Get a feeling for the mean and variance for each test across the sensors – is the variance the same (with reason)? What about across the 3 different sensors
    - Present results in a table. Use units of inches or millimeters as well as reporting time.
    - Note Ed is making a setup to hold the sensors on a yardstick to aid in this txperiment.
c) Connecting the Arduino to get same results as scope
    - We now want to use the Arduino to obtain results consistent with the analog measurements of part b.
    - Make sure your timer or interrupt has enough resolution – you may have to experiment.

- Validate you approach by duplicating a few of the measurement done in part b. Pick the intermediate performing sensor – not the best.
- At this point you should be able to match results within some error. Try for less than 5 %.
- Pick a data set and see if you can get a plot of the data centered around the mean and showing standard deviations. Does it look gaussian?

d) Sensor Calibration

- We would now like to get plots of the chosen ultrasonic sensor's statistics mean and variance (using the distance formula with speed of sound) for different locations from the target – at least 6, 12, 18 and 24 inches – if time permits do a few more points. Use at least 100 measurements to get the data but more is better
- It is important to physically measure the distance from the sensor to the target using a ruler etc. Try to be as accurate as possible.
- Make a plot comparing the mean of sensor reading (with an "ellipse of uncertainty", something like a +/-3 standard deviation bar) with the measured data.
- Is there an offset between the ground truth and the transducer? If so discuss why and adjust the formula for the best fit.

At this point we should have the statistics for at least one sensor
and a formula that relates it to ground truth/calibration data.

2) Simulating a moving target - Tracking position with an alpha or position and velocity with alpha-beta Kalman filer

- Since we do not have a moving target the objective is to simulate one.
- To do this we will use the yardstick setup with you sensor and set the sensor "close" to some value such as every 2 inches. Don't use each inch values set the sensor between +/-1/4 inch (to be refined) of each position. Record the ground truth.
- Take an ultrasonic measurement at each point
- After all data has been collected process it through the Kalman filter
- Present plots and results in a table.
- More on this in class on Monday

Some general comments or check list items

- Show appropriate signals, and data types on diagram

What to turn in (per group max 3) :

- 3-5 page terse memo showing detailed system diagram, key waveforms, and results. Make sure figures and plots have numbers and descriptive titles. Use tables and make sure you talk to results in tables. The memo must not leave questions unanswered – i.e. somehow show data types etc.
- Video of working system with voice over describing the scene (upload) Show a few examples that may be summarized in the memo.
- Note each group must have at least one CE and one EE member
- Make sure that you have read the memo and that it is consistent across sections and plots