ECE-CT590Computing and Control, Spring 19-20
Kalman Filter Project: Revision June 3, 2020

Note: this is an updated version of the document which was first posted in Week 5.

READ THIS FIRST BEFORE USING THE TEMPLATE

Objective:

The objective of this project is twofold:

1) To compare the static ranging data from an ultrasonic transducer processed by:
   a. averaging and
   b. alpha Kalman filter

2) To simulate a Kalman Filter based **alpha-beta target tracking system** using ultrasonic transducer data to simulate the position of a moving target.   The motion is simulated by assuming that there is a fixed time T between noisy position samples that are spatially separated.

Background:

- Your team should have statistics and calibration curve data for an ultrasonic sensor.
- Notes are provided to estimate the variance of the state noise – this was also discussed in class.
  - We posted a standard deviation $\sigma_\omega = \frac{1}{6}$ value which assumes a displacement variation of ¼ inch based on T = 1 update.   You have to adjust if you are using a different T especially for either the alpha or alpha beta filter

Ultrasonic Transducer measurement data

If you have data from more than one ultrasonic transducer pick the ultrasonic transducer in the middle range of variance – it must have variance that is reasonable. If you only have a single transducer use those values. See the posted variances for the class.

1- Using your version of "fixtures from the 2^{nd} floor window" and yardsticks gather multiple measurements from the transducer at various location –
2-
   - At least 10 measurement for each static point -but more is better (most people have N around 100) – do not move the transducer once located (i.e.   take all measurements at say 10.2 inches, then move to another value)
   - Make sure to record "ground truth" as exactly as possible.
     - You don't need to be on the inch marks exactly, the state variance is +/- ¼ inch (assuming T = 1) so you recorded ground truth should vary by that range.
     - Mix up the static points right on or between +1/4 and -1/4 of inch marks (i.e.   make ground truth   10.1   14.9 etc)
   - Do at least 20 locations, separated nominally by 1 inch but the more the better

- MAKE SURE TO USE THE SAME TRANSDUCER for all the measurements

Processing the data

Estimate of a single position by multiple measurements

Averaging

- For each data set (at a measurement point) use the averaging process described in the notes. You need the average of the measurement noise. Note you may not have "n_bar" but if you generated a calibration curve it would be included. Compare the values to ground truth as well as the variance band to ground truth

1 MEASUREMENT	$\hat{x}_1 = y_1 - \bar{n}$	$\sigma_{\tilde{x}_1}^2 = \sigma_n^2$
K MEASUREMENTS	$\hat{x} = \frac{1}{k}\sum_{i=1}^{k} \hat{x}_i$	$\sigma_{\tilde{x}}^2 = \frac{1}{k}\sigma_n^2$

- So assume you have a nominal distance of 10 inches, and you take 100 easements – report the average +/- 3 standard deviations

Alpha filter

- Implement an alpha filter to process each individual set of data (i.e. at each nominal measurement point). Remember this was the model of the flagpole blowing in the wind. Let T = 1 (see notes) and computr alpha using Kalata's paper.
- For each data set, plot the stem plot of the corrected position, vs samples, the average value and the error bands. Same as you did for the preliminary memo
  - Use the same noise and state covariance to process each set.
- Look at how the data falls within variance bands for each measurement set. See if the variation between the bands is changing. For instance at 10 inches are we closed to the mean and at 25 inches does the data vary more about the mean.
- Make some statement and graphic to describe what (if anything is going on)

Simulation of Moving Target and the Alpha-Beta Filter

- This is the model of the transducer moving at a constant velocity, i.e., train on tracks). For instance, if we mov 1 inch per second and data is spaced 1 inch apart then T = 1 and we say each measurement occurred at 1 sec. You can adjust T up or down. Compute out how fast this is in miles-per-hour and pick some reasonable number. You should also try a value of T = 0.1 and see what happens.
- Process the data with an alpha-beta Kalman filter – you need to computer alpha and beta from the noise and state variances using Kalata's paper (do not use the same alpha as the alpha filter). Remember this is a matrix equation and K(k) and P(k|k) are fixed values,
- Make sure units are correct

- You should have at least 10 measurements for each of the position points, break them up into sets of 10 so you have 10 different sets of data each representing measurements of the transducer moving along its length. Randomly choose one form each column.
- Process each set and plot position vs time and velocity vs time. Use stem plots. Note we expect the velocity to be "constant" You can minimize any startup artifacts by looking at Kalata;s paper track initialization.
- Make another plot thas shows time vs ground truth and pick one or more of your data sets and overlay this result. For each point does the Kalman filter provide a better estimate than just the averages you found for the singe point. Show _/-3 sigma for the position error from Kalman filter. You may have to blow up a few points to illustrate.

- Do a phase plant plot for Kalman filter output, in which you plot velocity vs x. Use red circles to illustrate the points. Next overlay with ground truth as black astericks. Then plot the error ellipse at each Kalman Filter point.. Ground truth should be inside the error ellipse. Note you should be able to reverse roles of ground truth and KF data.
  Remember phase plot is horizontal axis position, vertical axis velocity