EEE 515 **HOMEWORK ASSIGNMENT 4**

Due on December 1st, 2023 at 11:59 pm

Problem 1. Exploring Epipolar Geometry (50 points) In this problem, we will explore several concepts in camera calibration and epipolar geometry.

1. **Camera Calibration:** Using your cellphone (or equivalent camera of your choice), take several pictures of a checkerboard. Then report the camera intrinsic matrix K as well as the resulting reprojection error you receive. You can leverage OpenCV functions as mentioned here: `https://docs.opencv.org/4.x/dc/dbb/tutorial_py_calibration.html` to help you with this.
2. **Fundamental matrix:** Take several pictures of a household object you are interested in scanning, using the same camera you used in the previous step. Pick two representative pictures, and compute the fundamental matrix between the two images. Here the OpenCV tutorial `https://docs.opencv.org/3.4/da/de9/tutorial_py_epipolar_geometry.html` will be useful here. Report the fundamental matrix, and visualize points in one image and their corresponding epipolar lines in the other image (and vice versa) in a figure.
3. **Essential matrix:** Compute the essential matrix given the results you have computed in the prior two steps.

Problem 2. Implementing Kalman Filtering (50 points) In this problem, we will actually implement Kalman filtering for two scenarios: estimating a constant voltage value of an ADC and tracking a linearly moving 1D object. Note that this link: `http://www.cs.unc.edu/~welch/media/pdf/kalman_intro.pdf` will be helpful in setting up the Kalman filter.

(a.) **Estimating a constant voltage:** Suppose we have a voltage of 0.44 Volts coming in from an ADC, but its corrupted by white noise. So our process model is

$$x_k = x_{k-1} + w_k$$

with w have noise variance $1e-5$. Similarly our measurements are

$$z_k = x_k + v_k$$

where v has noise variance 0.01^2. Implement a Kalman filter to estimate the constant voltage. Plot the ground truth, the noisy measurements, and the output of the Kalman Filter. What is the effects of increasing noise in either the process w or measurement v?

(b.) **Tracking a 1D moving object:** Now suppose our state variable $X = [x, \dot{x}]^T$ contains the position and velocity of a 1D moving object. The process model

$$X_k = AX_k + W_k$$

should have $A = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$, and W has an diagonal covariance matrix with both entries $= 1e - 5$. The measurement model

$$Z_k = HX_k + V_k$$

with H only selecting the position state of the object, and V having a diagonal covariance matrix with both entries $= 10$. Implement a Kalman Filter, and plot the ground truth, the noisy measurements, and the output of the Kalman Filter. What is the effects of increasing noise in either the process w or measurement v?

Problem 3. Extra Credit: NeRF Studio (20 points) Install NerF Studio `https://docs.nerf.studio/index.html`. Then capture your own dataset of a 3D scene you want to represent (either as images or video), show the resulting 3D reconstruction using NeRF Studio. [20 points extra credit]