MAE 298 Estimation Theory and Application

Spring 2021

Homework 3

Due Tuesday 05/18/2021 on Gradescope

1. Design a Kalman filter to estimate the battery SOC based on the linear battery model derived in Homework 2.

   a. Write the equations for Kalman filtering of SOC. Use the LINEAR equivalent circuit battery model and treat the battery SOC as the only unknown state to be estimated.

   b. Implement the Kalman filter in Matlab. Use the current and voltage measurement data in the file "IV_data_linear.mat". Assume we know that the initial SOC = 1, $w_k \sim N(0, 2.5\times10^{-7})$ and $v_k \sim N(0, 10^{-4})$. The battery parameters are the same as in Homework 2. Submit a plot comparing the actual battery SOC (available in "IV_data_linear.mat"), the SOC estimation based on KF, and the open loop estimation (3 curves in one plot).

   c. Solve the algebraic Riccati equation to obtain P_∞ (the steady-state value of $P_{k|k-1}$), and then find the steady-state value of $P_{k|k}$. Compare it with the final estimate of $P_{k|k}$ from the Kalman filter (provide the plot). Do they match?

   d. Submit a plot comparing the histogram of the SOC estimation errors with the Gaussian distribution $N(0, P_{end})$, where P_{end} is the final estimate of $P_{k|k}$ from the KF. Do they match?

2. Design an extended Kalman filter (EKF) to estimate the battery SOC based on the nonlinear battery model derived in Homework 2.

   a. Write the equations for extended Kalman filtering of SOC. Use the NONLINEAR equivalent circuit battery model and treat the battery SOC as the only unknown.

   b. Implement the extended Kalman filter in Matlab. Use the current and voltage measurement data in the file "IV_data_nonlinear.mat". The battery open circuit voltage and its slope at a specific SOC can be interpolated from the provided look-up tables "OCV_table.mat" and "OCV_slope_table.mat". Submit a plot comparing the actual battery SOC (available in file "IV_data_nonlinear.mat"), the SOC estimation based on EKF, and the open loop estimation (3 curves in one plot).

   c. Submit a plot comparing the histogram of the SOC estimation errors with Gaussian distribution $N(0, P_{end})$, where P_{end} is the final estimate of $P_{k|k}$ from the EKF. Do they match? Why?

3. Run the linear Kalman filter you designed in Problem 1 using the data from file "IV_data_nonlinear".

   a. Submit a plot comparing the actual battery SOC, the SOC estimation based on linear Kalman filter, and the open loop estimation.

   b. Submit a plot comparing the histogram of the SOC estimation errors (of the linear Kalman filter) with Gaussian distribution $N(0, P_{end})$, where P_{end} is the final estimate of P from the linear Kalman filter. Do they match?