Laboratory 3 for ABE 424

Total points: 100

In this laboratory, we will implement a full-blown GPS-INS Extended Kalman filter

The learning outcomes are:

1. Understand Kalman filters and EKF
2. Implement Extended Kalman filter software in Python and ROS
3. Write software for EKF with GPS-INS integration and evaluate it against real data obtained in lab 2
4. Present report and analyze results for robustness
5. Plot comparisons between the provided real data and the estimates from your Kalman filter for all filter states, including bias. Plot the covariance of the estimates as a 2σ band around the estimated states.
6. Present code and get evaluated on style and readability in code to improve your coding skills as a roboticist

Background: GPS-INS sensor fusion is a key and critical part of mobile robot localization, especially outdoors. We have studied in class in detail the operational principles of GPS and INS, we have also derived the mathematical formulations for Bayesian sensor fusion problems and its extension to this problem through the Extended Kalman Filter. The goal in this lab is to bring all of this to practice by learning to create high-quality real-time implementable software for GPS-INS fusion.

Note that this lab has 2 possible ways you can complete it, more details in the lab:
1. Using a ROS BAG, for this use the folder ROS TEMPLATE
2. Using a .mat file for the data, for this use the MAT TEMPLATE

Questions for the lab report and points:

Q1: Implement the Extended Kalman Filter with the given data as instructed in the lab using Python and in ROS. Use your experience from Lab 1 to build the ROS nodes to grab the GPS, IMU, Encoder, and other relevant data. Publish the perception solution in a ROS node as instructed in the lab. (80 points)

Q2: Evaluate the performance of the Kalman filter for different values of Q and R matrices (10 points), in particular, try the following different cases and qualitatively describe what happens to the estimation errors and covariance. Is the filter fairly robust to Q and R?:

$$R = [.1\ .1\ .1\ .1\ .1\ .1]$$

$$R = [.01\ .01\ .01\ .01\ .01\ .01]$$
$$R = [10\ 10\ 10\ 8\ 8\ 8]$$
$$Q = 0.0001 * Q_{original}$$
$$Q = 100 * Q_{original}$$

Q3: Set the R_GPS to zero (I.e. assume the GPS is mounted at the CG), what happens to position estimates and the attitude estimates? Explain why it happens. (10 points)