HW #3 Due Oct 5, 2025 10 PM EST

Title: Implementing Kalman Filter for GPS and IMU Fusion

In this assignment, you will implement a Kalman Filter to estimate the position and orientation of a vehicle from a GPS and an IMU (Inertial Measurement Unit). GPS provides global position information but can have accuracy issues due to signal obstructions and multipath errors.
IMU provides high-frequency acceleration and angular velocity measurements but suffers from drift over time. The idea is to fuse the data from these sensors and improve the accuracy and reliability of pose estimation for navigation applications.

Data : We have collected data from both GPS and IMU using NUANCE, Field robotics's Lab's Autonomous car. The data is collected as a rosbag. You can find the data here : https://drive.google.com/file/d/13NTbaSxY7uYbRrld7iVXB27czxcrRTL9/view?usp=drive_link

Note that there are two GPS and IMU rostopics being published. Use "/gps/fix" and "/imu/imu_uncompensated" for your algorithm.

Part 1: Kalman Filter Implementation

Code up the Kalman filter to compute pose estimates using Python. Define and write up the equations for your process and measurement models, their covariances, and parameters in your jupyter notebook. Define and report your initial conditions as well. Develop functions for prediction and correction steps and estimate the state iteratively.

Implement a kalman filter to estimate 2D (x,y,theta) pose of the vehicle by fusing GPS and IMU measurements. You are free to use constant velocity model for the IMU or include acceleration component.

You can ignore computing accelerometer and gyroscope biases for this project. Estimate them initially by averaging the readings at rest and subtracting them from your readings to unbias the measurements. We can assume that the biases are constant for this project.
You can use scientific Python libraries such as numpy, but the process model, measurement model, and covariance update equations must be programmed by yourself. You are encouraged to ask questions and discuss on piazza. After you are done please check in your code, results, and writeup (a python notebook with all three would be perfect) into your gitlab accounts.

Part 3: Discussion and Analysis
Plot the raw GPS readings, Deadreckoned IMU estimates and the Kalman filtered state estimates of both the translational and rotational components. Reflect on the results and discuss the advantages and limitations of the Kalman Filter fusion in improving position estimation. Include any additional graphs, and visualizations to support your findings.

If you are feeling bold and brave

- Estimate 6 DOF poses using EKF implementation. (Optional)

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