Introduction to Data Science:
Homework 3 - Estimation

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In this homework, you need to write KF/EKF code for estimating IMU and laser data.

Compress all of your code and pdf files into a zip file. Then upload it to LMS system on time. Please cite references (e.g., websites or books) if you learn something from them.
NOTICE: DO NOT use any toolbox for this homework. If you use any library, you should make sure it is included correctly. If your code cannot independently run on Prof. Tseng's Matlab. You only got partial points.

1. Assumptions of Kalman filter (10%):
Give two examples in which the assumptions of Kalman filter do not hold.

2. Orientation estimation using a gyroscope and a magnetometers via Kalman filter (20%):
Given 2 axes information (ω_z, z_θ), estimate the angle (θ_z) along axis Z via a KF (see Fig. 1).
2.1 Find the following terms/values of KF (1)X (2)u, Z (3)A, B, C (4)R (5)Q. (10%)
2.2 Write KF code to estimate θ using MATLAB. (10%)
gyro_data1 is collected when the system rotated at 5 rad/s. heading_estimation_data1 is collected when the system is stationary. heading_estimation_data2 is collected when the system rotated. Hence you should use gyro_data1 for finding R, heading_estimation_data1 for finding Q and heading_estimation_data2 for sensor fusion. Read these data files using MATLAB. In heading_estimation_data1 and heading_estimation_data2, the first column is ω_z data and the second column is z_θ. The units of gyro and z_θ are rad/s and rad, respectively. dt is 0.01 sec.

3. Inclination estimation using a gyroscope and an accelerometer via extended Kalman filter (20%):
Given 6 axes information ($\omega_x, \omega_y, \omega_z, a_x, a_y, a_z$) of Minibot (use getimu.py to collect data), estimate the angle (θ_x) along axis X via an EKF. The axes information is shown in Fig. 2.
3.1 Find the following terms/values of EKF (1)X (2)u, Z (3)A, B, C (4)R (5)Q. (10%)
3.2 Collect 10 seconds IMU data and write EKF code to estimate θ_x using MATLAB. (10%)
Plot $\hat{\theta}_x$, $\theta_{x,acc}$, $\theta_{x,gyro}$ v.s. iterations, where $\hat{\theta}_x$ is the estimated θ_x by EKF, $\theta_{x,acc}$ is the estimated θ_x by accelerometer, and $\theta_{x,gyro}$ is the estimated θ_x by gyroscope using integration. The units of accelerometer and gyro are cm/s^2 and $degree/s$, respectively. dt is 0.02 sec. [Note:] During data collection, you should rotate Minibot along axis X around $-45 \sim 45$ degrees and then let it stationary for $2 \sim 5$ seconds.

4. Target estimation using laser data (50%):

Given a leg dataset including laser data X and labels Y, the data information is as follows:
There are 720 laser data points at each time step. The laser data was divided into several segments S_t^i, where t denotes the time step and i denote the i-th segments. The data is adopted for Adaboost detection and KF tracking. The goal is to detect and track the target location.
1) Find the following terms/values of EKF (1)X (2)u, Z (3)A, B, H (4)R (5)Q. (10%)
2) Simulation: Track a 2D target with circular motion using KF with CV model. (10%)
The target's location is at $(x, y) = (r * cos\theta, r * sin\theta)$, where $r = 10$, $\theta = 0.174 * timer_i$ and $timer_i$ is the index of a timer counter.
3) Track the person location using KF with CV model. (30%)

5. (Extra credit) Estimation on Mars (20%):

If a robot's estimation system is built based on the gravity of the earth, what could happen when this robot moves on Mars?

Code Delivery:

Matlab code (.m file). The file name should be $Tracking\_sim.m$ and $Tracking\_ex.m$. Compress all of your code into a zip file.

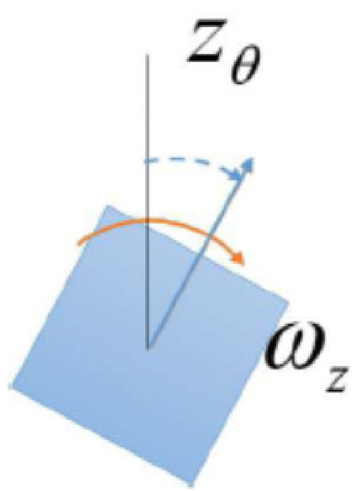

Figure 1: Illustration of problem 2

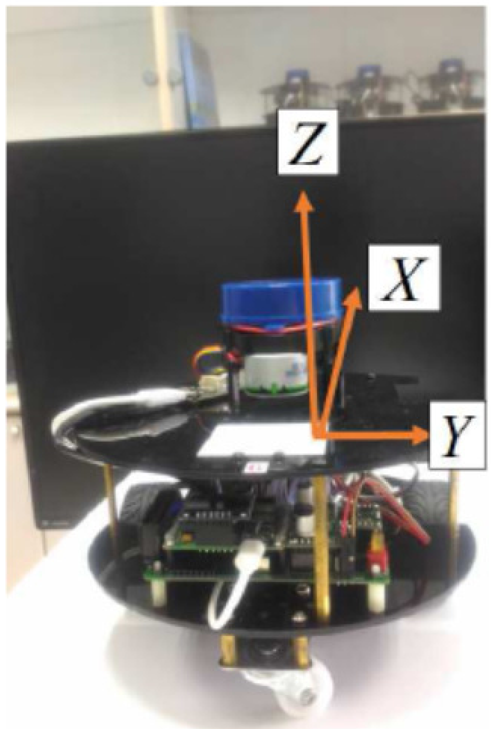

Figure 2: Three axes of Minibot