Final project
Tracking of a maneuvering vehicle using GPS and radar data.
Linear and Extended Kalman filter.

The objectives of this assignment are to encourage you to think creatively and critically to extract a useful signal from noisy experimental data, find best estimation method of a dynamical process and make forecast of its future development.

This assignment is to be done in groups of 3-4 students, and only one document is submitted for the group. You may also freely talk with students in other groups, but the final documents that you submit must be done only by your group.

Formulation

1. What to do if your vehicle does a strong maneuver?

2. This project consist of 2 parts.
   (a) There are GPS measurements available
   (b) There are data from a radar available.

Part 1. Tracking a maneuvering vehicle using GPS data

1. There are GPS measurements of coordinate x and y for your availability of a vehicle motion.
   files/folder/Final projects/Project 11/data/GPS/GPS..mat
   The file contains variables z corresponding to the GPS measurements of two vehicles

   The format of GPS in Matlab:
   First row – measurements of the coordinate x
   Second row – measurements of the coordinate y

   The format of txt data
   Element in the first column - measurements of the coordinate x
   Element in the second column - measurements of the coordinate y

3. How you can track the motion reliably in these conditions?
   First construct a linear Kalman filter

   State vector $X_i = \begin{vmatrix} x_i \\ V_i^x \\ y_i \\ V_i^y \end{vmatrix}$

   (a) Let's assume that the true trajectory X_i is described by a motion with normally distributed unbiased random acceleration a_i with variance $\sigma_a^2 = 0.01^2$ for both a_i^x, a_i^y.

$$x_i = x_{i-1} + V_{i-1}^x T + \frac{a_{i-1}^x T^2}{2}$$

$$V_i^x = V_{i-1}^x + a_{i-1}^x T$$

$$y_i = y_{i-1} + V_{i-1}^y T + \frac{a_{i-1}^y T^2}{2}$$

$$V_i^y = V_{i-1}^y + a_{i-1}^y T$$
$$T = 1$$

(b) From a prior information you know that the variance of measurement noise is $\sigma_\eta = 10^2$ for both $\sigma_{\eta_x}, \sigma_{\eta_y}$

(c) Initial filtered estimate of state vector $X_{0,0}$

$$X_0 = \begin{vmatrix} 0 \\ 0 \\ 0 \\ 0 \end{vmatrix}$$

Initial filtration error covariance matrix $P_{0,0}$

$$P_{0,0} = \begin{vmatrix} 10^5 & 0 & 0 & 0 \\ 0 & 10^5 & 0 & 0 \\ 0 & 0 & 10^5 & 0 \\ 0 & 0 & 0 & 10^5 \end{vmatrix}$$

4. Plot the estimation results (Prediction and Filtration) independently for X and Y. We see that the maneuver is not greatly detected.

5. How we can improve this?
   Let's analyze the filter residual
   $$v_i = z_i - HX_{i,i-1}$$
   Residual v_i indicates the strong mismatch between measurements and predictions. Thus, at these moments we should increase the prediction error covariance matrix $P_{i,i}$

   For instance of absolute value of v_i is greater than the $3.5\sigma_\eta$ both for X and Y then you should indicate that $P_{i,i}$ is again huge
   $$P_{i,i} = \begin{vmatrix} 10^5 & 0 & 0 & 0 \\ 0 & 10^5 & 0 & 0 \\ 0 & 0 & 10^5 & 0 \\ 0 & 0 & 0 & 10^5 \end{vmatrix}$$

Part 2. Tracking a maneuvering vehicle using radar data

1. Repeat the same task, but using radar data and Extended Kalman filter/

2. There are radar measurements of range D and azimuth β for your availability.
   files/folder/Final projects/Project 11/data/Matlab/radar.mat
   Measurements are available every second.

   The format of radar.mat in Matlab:
   First column – measurements of the range D in meters

Second column – measurements of the azimuth β in radians

The format of txt data
Element in the first column - measurements of the range D in meters
Element in the second column - measurements of the azimuth β in radians

3. The state vector and variance of state noise is the same as in the first part.

4. The measurement vector consists of range D and azimuth β and thus the measurement equation is nonlinear.

5. From a prior information you know that the variance of measurement noise of range D is $\sigma_D^2 = 50^2$ (in meters), and the variance of measurement noise of azimuth β is $\sigma_\beta^2 = 0.004^2$ (in radians).

6. Use coordinate transformation of measurements from polar to Cartesian coordinates to compare pseudo-measurements converted from polar to Cartesian coordinated to compare with filtered and predicted components of state vector.

7. To track the maneuver please apply the similar approach with controlling the filter residual comparing it with the $3.5\sigma_D$ and $3.5\sigma_\beta$.

8. Which filter is more accurate, linear or extended one?

October 19 and October 21

1. Present your results with charts in 15 minutes.
   The presentation should include the problem formulation, why it is important, nice figures, grounds why the chosen method is the best method (visual analysis, quantitative criteria, simplicity of implementation, and any other arguments). Which regularities are found. Discuss what are the risks of obtained estimations and conclusions about the process. Make general conclusions about the efficiency of method.

   Try **to share** with the audience a practical and useful idea behind the project, **to make the overall exchange of practical and efficient tools and approaches and for what they can be applied.**

2. Submit the final version of your project to canvas.