Advanced Control Systems

Detection, Estimation, and Filtering

Graduate Course on the Mechanical Engineering PhD Program

Spring 2012/2013

4th and 5th Problem Sets

This is the fourth and fifth problem sets, in the Advanced Control System course in Detection, Estimation, and Filtering. These problem sets consists of a positioning system design and analysis example, supported on a sensor network. The tools and methods previously studied in the course can all be used to address and solve the problem at hand. The solutions of the problems should be explained in detail, some requiring a MATLAB implementation.

Problem Description:

The 2D position of a mobile user must be known, to help to implement a solution in a critical infrastructure. To solve that problem a sensor network composed by mobile measurement beacons and static transponders is used. The transponders are installed at coordinates: #1=(0,0), #2=(100,0), and #3=(0,100) and a beacon is mounted on a mobile platform with computing capabilities. The systems in this sensor network are able to measure the distances between all the transponders and the beacon, once a second. A set of positioning algorithms must be derived, studied, and tested in real conditions. For that purpose a set of experiments detailed next, will be carried out.

Part I – Mobile platform stopped

To characterize the sensing devices to be used in the positioning system, the transponders are installed and switched on, the beacon is placed stationary on a point in the mission scenario, and data were collected (see file stop.m).

[10 points] Characterize the uncertainty on the distance measurements.

[20 points] Resorting to any methodology studied in the course, propose an estimator to compute the position of the platform. Characterize the performance of the proposed estimator, resorting to Monte Carlo techniques.

[20 points] Derive the Cramer-Rao lower bound for that configuration. Suggestion: as the problem is nonlinear, linearization techniques can be helpful, even if approximate results are obtained.

[10 points] Comment on the results obtained and on the attainable results, according to the CRLB.

[20 points] If a fourth transponder is available, discuss the installation coordinates, in order to maximize the overall system performance, i.e. to minimize the estimation error.

Part II – Straight line movements

The next set of experiments consists of executing straight lines. The results obtained are available in: str1.m, for a straight line between two transponders, and str2.m for other straight line in the mission scenario

[10 points] Resorting to any methodology studied in the course, compute the position of the platform, for each position of the first experiment, given the measurements of the appropriate pair of transponders.

[20 points] Evaluate the CRLB for this particular case (using both two or three transponders).

[10 points] Discuss what is the best strategy to obtain the minimum estimation error?

[10 points] Implement an alternative strategy consisting of estimating the parameters of the straight line.

[10 points] Compute the estimation errors in this last case, at each second. Compare with the errors previously computed. Discuss the results.

[20 points] Repeat Part II for the second straight line.

Part III

During the real time operation of the system, a causal solution is required to be implemented. The collected data are stored files user1.m and user2.m, for a straight line and a generic trajectory, respectively.

[20 points] Design a Kalman filter for the case where the target motion is described by the very simple dynamics

$$
\begin{cases}
x(k+1) = x(k) + v_x(k) \\
v_x(k+1) = v_x(k) + w_x(k) \\
y(k+1) = y(k) + v_y(k) \\
v_y(k+1) = v_y(k) + w_y(k)
\end{cases},
$$

where wx and wy are zero mean white Gaussian noise with covariance 0.0001 m2. Use only the data from transponders #1 and #2, in the first experiment. Implement the Kalman filter in MATLAB/Simulink, for several different initial conditions. Plot the state and error covariance evolution along the experiments.

[20 points] Discuss the stability and the frequency response for this filter. What would change if more accurate sensors would be used (i.e. lower measurement covariance noise).

Paulo Oliveira

IST, June 11th 2013

Due date: June 30th 2013

Bom trabalho ;)