P1

Optimal Online Nonlinear/Non-Gaussian State Estimation

Please read through this document and complete the coursework as required. The coursework submitted (including the relevant program source files) should be all your own work and reference to, quotation from, and discussion of other work should be correctly acknowledged.

Note: This coursework accounts for 30% of your final mark for this module. Please spend no more than 30 hours on this assignment.

Optimal Online Nonlinear/Non-Gaussian State Estimation

Consider the following discrete time system

$$x_k = \frac{x_{k-1}}{2} + \frac{25x_{k-1}}{1+x_{k-1}^2} + 8\cos(1.2k) + v_{k-1}$$
$$z_k = \frac{x_k^2}{20} + n_k$$

where v and n are independent zero mean Gaussian white noises with variances $Q = 10$ and $R = 1$, respectively. This example has been used as a benchmark problem in many publications (please refer to [1] and the reference therein).

Task 1: Assuming $x_0 \sim N(0,1)$, use the Monte Carlo method to estimate the pdfs $p(x_1)$, $p(x_{50})$ and $p(x_{100})$. Explain why it would be problematic to use the traditional Kalman filter to estimate the unknown state given the measurement data z_k.

Task 2: Suppose that during one experiment, the output measurements $z_k, 0 \le k \le 100$ have been recorded. Use the extended Kalman filter, grid based method and particle filter to estimate the unknown state information $x_k, 0 \le k \le 100$.

Task 3: Now suppose that the actual unknown state information $x_k, 0 \le k \le 100$ is available. Define suitable measures to compare and evaluate the performance of the different filtering techniques in Task 2. Explain why there are differences in their performance.

Task 4: Explore how the performance of the three filtering techniques in Task 2 can be improved. Re-estimate the unknown state information using these improved schemes. Compare the estimation results with those obtained in Task 2 & 3. Do they support your theoretical prediction?

Task 5: Critically evaluate your work. Have you achieved the objectives? What problems did you find during this work? What conclusions can you draw from your design? From the experience of this work, what do you need to consider when solving a practical problem?

References

1. S. Arulampalam, S. Maskell, N. Gordon and T. Clapp, "A tutorial on particle filters for online nonlinear/non-Gaussian Bayesian tracking," *IEEE Transactions on Signal Processing*, vol.50, no.2, pp. 174-188, 2002.
2. D. Simon, *Optimal State Estimation: Kalman, H-infinity, and Nonlinear Approaches.* John Wiley & Sons, 2006.

Assessment of Your Work: This coursework accounts for **30%** of your final mark for this module. You will be asked to submit **a final report (30%)** and at a later stage to give a **10 minute presentation (10%)**. You will be asked to submit your report and relevant program files (with clear instructions on how to run the program) before the deadline (16:00 20/03/2020) using the ECS handin system.

1. **Report.** The project report should be written in the form of a formal **THREE page** length conference paper. A template is available on the IEEE Control System paper management website http://css.paperplaza.net/conferences/support/support.php

2. **Presentation.** You will be asked to give a formal conference presentation of your work, consisting of **a 7 minute presentation + a 3 minute Q & A**.