M.E. (Electrical) 2nd Semester Examination, 2012

Optimal Filtering Process (EE-1022)

Time : 3 Hours | Full Marks: 70

Answer any SIX questions
Taking any TWO from each Group

GROUP-A

1. a) What is a Kalman Filter? Why it is a popular tool for the technologists?
   b) What is a Wiener filter? Compare its operation with that of Kalman filter. [5+7]

2. a) What do you mean by a "Random variable" and a "Random Number? Discuss with the example of single die and two dice problems.
   b) Mention some of the properties of Auto-correlation function with example. [7+5]

3. a) What are 'time varying' and 'time invariant' systems? Explain 'observability' of a time invariant system.
   b) Discuss the differences among 'predicter', 'filter' and 'smoother'. [6+6]

GROUP-B

4. a) How deterministic least square method may be related with a Kalman filter algorithm?
   b) If the steady state gain of the Kalman filter approaches 0.9, comment on the stability condition of the discrete-time system given by

$$x_{k+1} = x_k + 2w_k$$
$$z_k = 1.5x_k + v_k$$

[6+5]

5. a) Discuss the differences between LKF and EKF methods.
   b) Determine the solution of x_k up to $k = 2$ around the estimated states for the system given by:

$$x_{k+1} = 1.5x_k^2 - 2x_k + w_k$$
$$z_k = x_k^3 + v_k$$
$$E\langle w_k \rangle = E\langle v_k \rangle = 0$$
$$E\langle x_0 \rangle = \hat{x}_0 = 0$$
$$\text{cov.}(w_k) = \Delta(k_2 - k_1)$$
$$\text{cov.}(v_k) = 1.5\Delta(k_2 - k_1)$$

[4+7]

contd.../2

6. a) What are the practical problems in implementing Kalman filter algorithms?

   b) What is a "Bad data" problem? How can it be overcome? [5+6]

GROUP-C

7. a) How the process and sensor disturbances can be modeled and handled by augmenting the states?

   b) A central air-conditioning system is represented by the following state-space equations:

$$\dot{x} = \begin{bmatrix} -4 & 2 \\ 2 & -7 \end{bmatrix} x + \begin{bmatrix} 3 \\ 0 \end{bmatrix} u + \begin{bmatrix} 0 \\ 1 \end{bmatrix} d$$

$$z = \begin{bmatrix} 0 & 1 \end{bmatrix} x$$

   where u is the control input and d is the process disturbance of external temperature having a periodic variation given by dynamics $\ddot{d} + 0.03\dot{d} + 0.01d = w$, where w is a white noise process. There is no known sensor noise dynamics. Get the augmented system state-space matrices. [6+6]

8. a) Define the terms 'terminal penalty cost', 'state weighting matrix' and 'input weighting matrix' with respect to the LQ control theory.

   b) How the LQG control problem can be separated into two completely decoupled processes of 'LQ estimation' and 'LQ optimal control'? Explain with diagram and relevant equations. [5+7]

9. Write critical notes on ***any two***: [2 x 6]

   a) Significance of 'Time update' and 'Measurement update' equations of Kalman Filter algorithm.

   b) DFRE and DCRE equations of discrete time LQG control problem

   c) Rounding-off error in Kalman Filter.

   d) Uncented Kalman Filter.