EE5327, Fall 2017
Extended Homework/Project 2
Due 12/14/2017

Extended Kalman Filter 100 points
Implement the van der Pol equation in Simulink as:

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = \mu(1 - x_1^2)x_2 - x_1$$

Use a 50 second simulation with a fixed step integrator with a time step of 0.1 seconds and initial conditions of the states to be [0.1, 0.1]. Assume $\mu = 1$. Add a process noise input just before the integrators with zero mean and set the true process variances to be [0.2, 0.1] for x1 and x2, respectively. Implement measurement noise added to the true states (which included the process noise effects) to create the measurement vector. Set the true measurement noise variance to be [0.015, 0.025] for x1 and x2, respectively. Make sure to give each random number generator a different seed.

Modify the MATLAB blocks you used in Homework 3 to implement the extended Kalman filter, noting that the dynamics are now nonlinear (so you'll have to compute the Jacobian and implement it in the predictor block) but assume the measurement equation is linear (i.e. H = eye(2)). Set the initial value of P to be eye(2) and the initial values of the estimated states to be [0.1, 0.1], the same as the true states. The variances of the process and measurement noises will be specified below as will the values of Q and R.

a) Take R to be diag([0.015 0.025]) and set Q=diag([2 1]). Plot the phase portrait of x2 vs x1 for both the true states (with process noise) and for the estimated states. Also plot on another graph +/-sqrt(P11) and the error x1_true – x1_estimated and another graph +/-sqrt(P22) and the error x2_true-x2_estimated. Also plot the time histories of the Kalman gain, K.
b) Now set Q = diag([0.2 0.1]). Repeat the plots done in part a) and note if the filter performance is better or worse and how the values of K differ from part a). Try again with Q = diag([4 2]]) and plot/note the changes.
c) Now set Q=diag([2 1]) and set R=diag([0.15 0.25]) and repeat the graphs. Then try setting R=diag([0.0015 0.0025]) and repeat. Comment on the effects of varying Q and R relative to the true noise variances in terms of the quality of the estimates.
d) Finally, from the knowledge you gained from playing with the Q and R terms, adjust those values to give what you find to be the 'best' results. Plot the K time histories of the optimally tuned filter.
e) Now set the initial value of the initial predicted states to be [-0.5, 0.5] and rerun the analysis with the values of Q and R you found in part d). Do you think you would have to retune the filter if the initial conditions change for this dynamic system?
f) Make sure to print out your predictor and corrector block scripts as well as a screenshot of the Simulink diagram as part of the report. Copy me on your submissions to Susan.