MECE-744: Nonlinear Controls **Computer Project #2**

Spring 2015-2016 (Spr: 2155) *Due 03-03-16*

Instructions: Use Matlab/Simulink to solve all problems unless otherwise indicated. Save your work in an m-file and a slx-file. Project write-up should include the following:

1. a project write-up with <u>clearly</u> defined answers to each problem.
2. a print out of the Matlab command window showing your Matlab solution answers. Clearly define each solution and the part to which it pertains.
3. a print out copy of your m-file program and any Simulink diagrams.
4. a print out copy of <u>clearly</u> labeled Figures and Plots
5. a soft copy of your program required to run all the problem parts (place it in the mycourses dropbox shell)

1. For the following nonlinear system shown below:

$$\dot{x}_1 = x_1\left(x_1^2 + x_2^2 - 4\right) + x_2$$
$$\dot{x}_2 = x_2\left(x_1^2 + x_2^2 - 4\right) - x_1$$

   a. determine the State Plane Portrait plot with x_1 on the horizontal axis and x_2 on the vertical i.e., (x_2 vs x_1). Indicate the directions of each trajectory on the State Plane Portrait plot.

   b. determine the system's equilibrium point using "fminsearch", try using $x_1 = 10$ and $x_2 = 10$ as your starting points for your "fminsearch"; make sure to print out the final values from the Matlab command window and include them in your report write up! You must use the following cost function:

$$J = \dot{x}_1^2 + 1000\dot{x}_2^2$$

   c. using "linmod" determine the system's linearized state-space model, make sure to print out the state-space model (i.e., the "A", "B", "C", and "D" matrices) from the Matlab command window and include them in your report write up!

   d. find the system's eigenvalues, damping ratios, and natural frequencies from the linearized state-space model (hint: use the "damp" command) and include them in your report with properly labeled units for the eigenvalues, damping ratios, and natural frequencies.

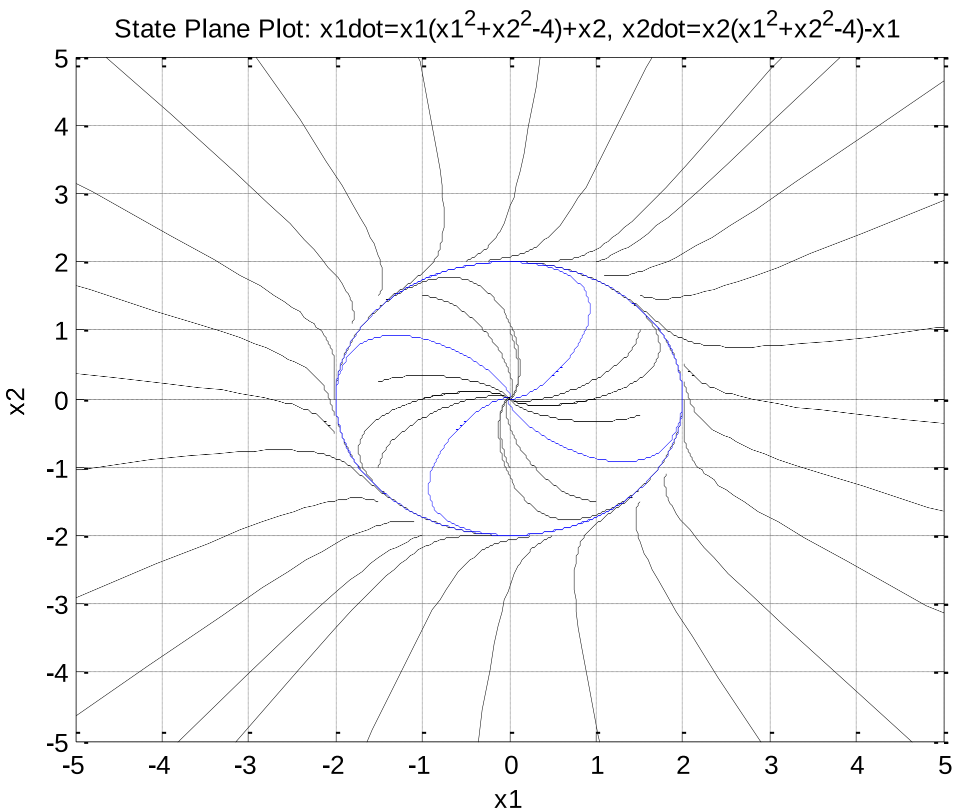
   e. Overlay a **5** second time history responses comparing the linear and nonlinear responses for x_1 (i.e., x_1 vs time) and x_2 (i.e., x_2 vs time) with the following initial conditions:

      1. $x_1(0) = x_2(0) = 0.4$
      2. $x_1(0) = x_2(0) = 1$
      3. $x_1(0) = x_2(0) = 1.4$
      4. $x_1(0) = x_2(0) = \sqrt{2}$

   Please include <u>**8**</u> separate plot overlay figures (x_1 vs time and x_2 vs time for each initial condition set shown above).

f. analyze the system's stability using Lyapunov's Direct Method (show your hand calculations). How does this result compare to your State Plane plot?

g. analyze the system's stability using Lyapunov's Non-Direct (Linearization) Method (show your hand calculations, including the derivation of the linearized "A" matrix using partial derivatives). How does this result compare to your State Plane plot?



State Plane Plot for Problem #1