# 330: 406 — Project #4
# Linearization and Equilibrium Points of Nonlinear Systems

Project due on April 17, 1997

The purpose of this project is to use the SIMULINK package to get block diagrams of nonlinear systems, system equilibrium points, and nonlinear system linearized models. Hint: Save block diagrams obtained as m-files, for example ex1.m and ex2.m. Use the SIMULINK functions `trim` and `linmod` to get the system equilibrium points and the linearized models.

**#1)** Consider the mathematical model of a simple pendulum

$$I\frac{d^2\theta}{dt^2} + mgl\sin\theta = lu(t), \quad \theta(t_0) = 0,\ \dot{\theta}(t_0) = 0$$

where $I = 0.1$ is the moment of inertia, $l = 1, m = 1$ are pendulum length and mass, respectively, $g = 9.8$ is the gravitational constant, and $u(t)$ is an external tangential force.

(a) Obtained the linearized models at the given nominal values $\theta_n(t) = 0$, $u_n(t) = 0, \dot{\theta}_n(t) = 0$, and $\theta_n(t) = \pi$, $u_n(t) = 0, \dot{\theta}_n(t) = 0$.

(b) Examine stability of the linearized models by finding the corresponding eigenvalues.

**#2)** Consider a nonlinear control system represented by

$$\begin{aligned} \dot{x}_1 &= u\ln x_1 + x_2 e^{-u}, & x_1(t_0) &= 1 \\ \dot{x}_2 &= x_1\sin u - \sin x_2, & x_2(t_0) &= -0.8 \\ y &= \sin x_1 \end{aligned}$$

(a) Set the initial guesses for finding the equilibrium points (note that nonlinear algebraic equations have many solutions) as $x_{1e}^{(0)} = 1, x_{2e}^{(0)} = 1$, $u_e^{(0)} = 1$, and set the desired output value at $y = 1$. Use the `trim` function to find the system equilibrium point in the neighborhood of the assumed initial guesses.

(b) Use the function `linmod` to obtained the linearized model of this system at the equilibrium point obtained in (a).

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