AEM 4321 / EE 4231: HW#1

1. **Block Diagrams**

   In the first lecture we discussed block diagrams for an automotive cruise control and an aircraft pitch control system. Consider a treadmill used by runners at a gym. Draw a block diagram for the speed control on such a treadmill. What are the plant, actuator, and sensor for this system? What is the reference signal and how is it set by the user? What is the key disturbance?

2. **Linearization**

   Consider the first-order nonlinear system:

   $$\dot{x} = f(x, u) \tag{1}$$

   where $f(x, u) := -x + \cos(x) - u^3$. Note that you can make x stay fixed at any value by appropriately choosing the input.

   (a) Given $\bar{x} = -1$, find the input $\bar{u}$ such that $f(\bar{x}, \bar{u}) = 0$.

   (b) Construct a `Simulink` model for this nonlinear system. Simulate the system with the initial condition $x(0) = \bar{x}$ and input $u(t) = \bar{u}$ for $t \geq 0$. Hand in a plot of x vs. time. There are many ways to construct this model in `Simulink`. One way is to use the `Math Function` and `Trigonometric Function` blocks in the `Math Operations` folder.

   (c) Linearize the nonlinear dynamics around the equilibrium point $(\bar{x}, \bar{u})$. You should get a model of the form:

   $$\dot{\delta}_x + a\delta_x = b\delta_u \tag{2}$$

   where $\delta_x(t) := x(t) - \bar{x}$ and $\delta_u(t) := u(t) - \bar{u}$ measure the deviation of the state and input from the equilibrium point.

   (d) Construct a `Simulink` model for this linearized system. Simulate the nonlinear system with the initial condition $x(0) = -0.9$ and input $u(t) = \bar{u}$ for $t \geq 0$. Also simulate the linear system with the corresponding initial condition and input. Plot x vs. time for both systems on the same figure. For the linearized system you need to carefully convert back and forth between the (x, u) and (δ_x, δ_u) coordinates.

   (e) Simulate both the nonlinear and linear systems with the initial condition $x(0) = 3$ and input $u(t) = \bar{u}$ for $t \geq 0$. Plot x vs. time for both systems on the same figure. This initial condition is much farther from the equilibrium point $\bar{x} = -1$. How closely does the linear approximation match the nonlinear system for this initial condition?

3. **Applications of Control**

   In the library, look at the 3 journals:

   - IEEE Control Systems
   - IEEE Transactions on Control System Technology
   - AIAA Journal of Guidance, Control, and Dynamics

   (a) Look through the articles informally and pick one that interests you. Attempt to read this article in "detail" skipping over the mathematics we have not covered (there may be a lot). Focus on understanding the problem being formulated:
   - What is the system/plant being controlled?
   - What sensors/actuators are being used?
   - What is the control objective?
   - What are the key issues? (Possibly including sensor noise, disturbances, model uncertainty).

   (b) In the abstract and introduction sections, highlight or underline the aspects that interest you and make sense. In the body of the paper, highlight paragraphs (or parts of paragraphs) that make sense. Look for block diagrams and try to understand the signals and subsystems in the diagram.

   (c) Write a 1 paragraph summary of the paper addressing most of the questions listed in part (a). Also, turn in the paper with the highlighted sections from part (b).