Tutorial #4
ELL-225: Control Engineering

Session: Semester-II (2022-23)

1. An IPMC (ionic polymer-metal composite) is a Nafion sheet plated with gold on both sides. An IPMC bends when an electric field is applied across its thickness. IPMCs have been used as robotic actuators in several applications and as active catheters in biomedical applications. With the aim of improving actuator settling times, a state-space model has been developed for a 20 $mm \times 10\ mm \times 0.2\ mm$ polymer sample (Mallavarapu, 2001):

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} -8.34 & -2.26 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$$

$$y = \begin{bmatrix} 12.54 & 2.26 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

where u is the applied input voltage and y is the deflection at one of the material's tips when the sample is tested in a cantilever arrangement.

(a) Find the state-transition matrix for the system.

(b) Find unit step response corresponding to zero initial condition of the IPMC material sample.

2. An automatic depth-control system for a robot submarine is shown in Fig. (1). The depth is measured by a pressure transducer. The gain of the stern plane actuator is $K = 1$ when the vertical velocity is 25m/s. the submarine has the approximate transfer function -

$$G(s) = \frac{(s+1)^2}{s^2+1}$$

and the feedback transducer is $H(s) = 2s + 1$.

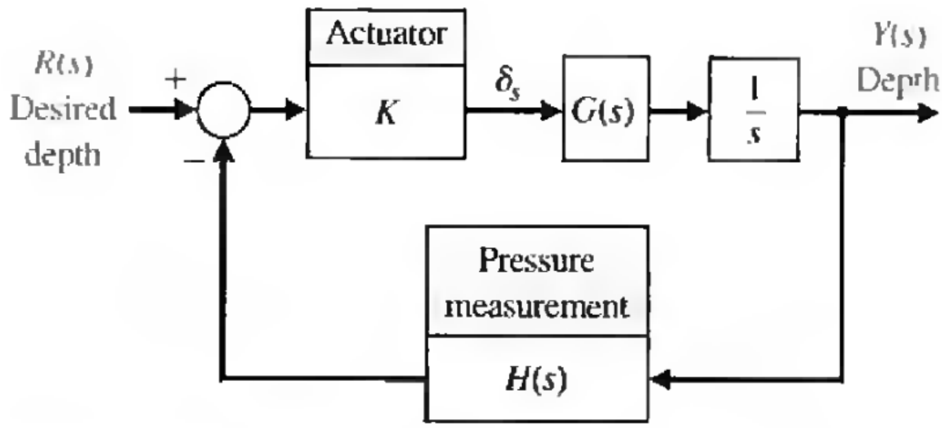

Figure 1: Submarine depth control

(a) Determine the state space representation of the system.

(b) Determine whether the system is stable.

(c) Determine the expression for time response when the system is subjected to unit step response.

3. A translational mechanical system model for a high-speed rail pantograph, used to supply electricity to a train from an overhead catenary was discussed in Tutorial 2 as shown in Figure 2 below. Represent the pantograph in state space, where the output is the displacement of the top of the pantograph $y_h(t) - y_{cat}(t)$.

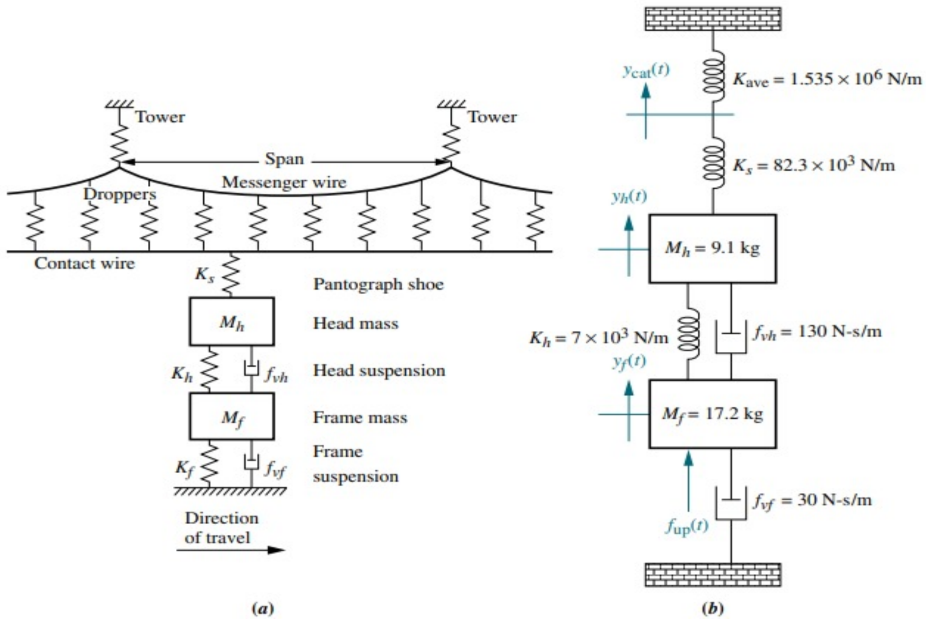

Figure 2: Pantograph-Catenary Model

4. In typical conventional aircraft, longitudinal flight model linearization results in transfer functions with two pairs of complex conjugate poles. Consequently, the natural response for these aeroplanes has two modes in their natural response. The "short period" mode is relatively well-damped and has high-frequency oscillation. The "phugoid mode" is lightly damped, and its oscillation frequency is relatively low. For example, in a specific aircraft, the transfer function from wing elevator deflection to nose angle(angle of attack) is

$$\frac{\theta(s)}{\delta_e(s)} = -\frac{26.12(s+0.0098)(s+1.371)}{(s^2+8.99\times10^{-3}s+3.97\times10^{-3})(s^2+4.21s+18.23)}$$

(a) Find which of the poles correspond to the short period mode and which to the phugoid mode.

(b) Perform a "phugoid approximation"(dominant-pole approximation), retaining the two poles and the zero closest to the; ω-axis

(c) Use MATLAB to compare the step responses of the original transfer function and the approximation.