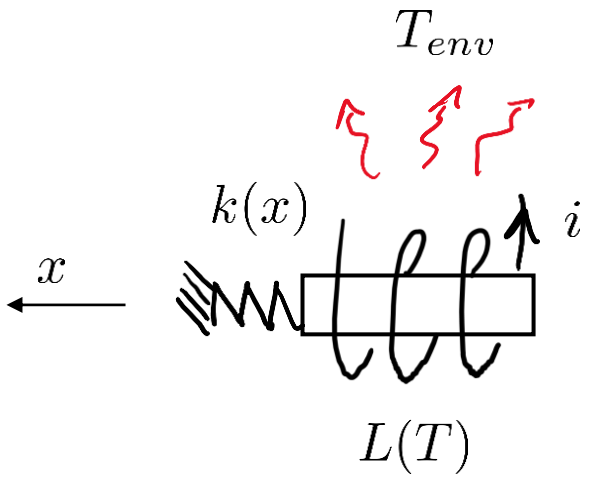
The nonlinear dynamics of an electromechanical actuator with nonlinear spring and inductance is:

$$m\ddot{x} + c\dot{x} + k_1 x + k_3 x^3 = \alpha i$$

$$\left(L_0 + \beta_1 T + \beta_2 T^2\right)\dot{i} + Ri = u$$

$$\dot{T} = \frac{1}{C_T}\left[Ri^2 - h\left(T - T_{env}\right)\right]$$




$x_1 = x$ Piston displacement

$x_2 = \dot{x}$ Piston velocity

$x_3 = i$ Current

$x_4 = T$ Temperature

$u = V$ Voltage (control input)

$C_T$ Thermal capacity $h$ Thermal dissipation coefficient

$T_{env}$ Ambient temperature $m$ Mass of the piston

$L_0$ Inductance at a reference temperature $T = 0$

$\beta_{1,2}$ Coefficients for the T-dependent inductance

$k_{1,3}$ Coefficients for the x-dependent stiffness

$\alpha$ Force constant $R$ Resistance

The nonlinear dynamics of an electromechanical actuator with nonlinear spring and inductance is:

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

$$\dot{x}_2 = -\frac{k_1}{m}x_1 - \frac{k_3}{m}x_1^3 - \frac{c}{m}x_2 + \frac{\alpha}{m}x_3$$

$$\dot{x}_3 = -\frac{R}{L(T)}x_3 + \frac{1}{L(T)}u$$

$$\dot{x}_4 = \frac{1}{C_T}\left[Rx_3^2 - h\left(x_4 - T_{env}\right)\right]$$

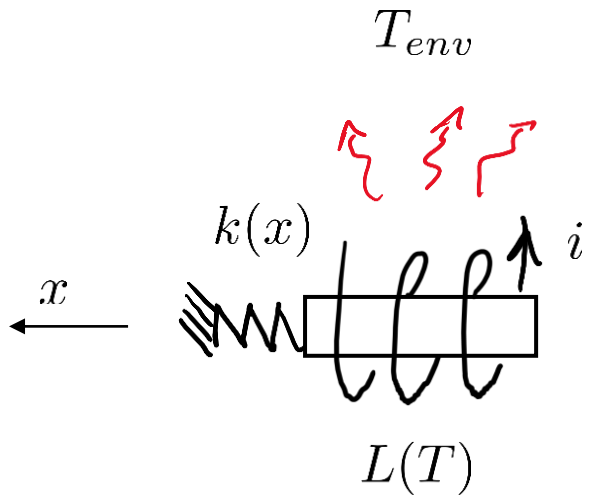
$x_1 = x$ Piston displacement

$x_2 = \dot{x}$ Piston velocity

$x_3 = i$ Current

$x_4 = T$ Temperature

$u = V$ Voltage (control input)




Design a LQR that operates around a certain reference voltage and employs a KF for estimate the full state. In addition to the full state feedback, provide an estimate of one of the characteristics constants starting from uncertain initial conditions.