Project Proposal

ECES 512

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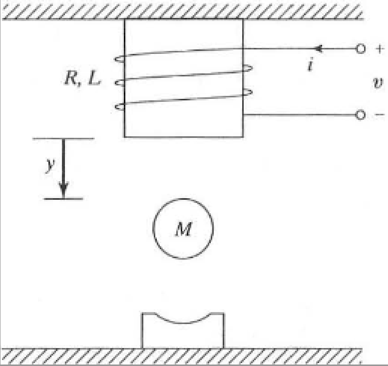
Electromechanical Magnetic-Ball Suspension

- Make an object levitate by controlling the current



Mathematical Model

Variables

- R - Resistance
- L - Inductance
- v - Voltage
- m - Mass
- K - Coefficient that relates force to the magnetic field
- g - Gravity
- i - Current
- y - Distance of Mass M to electromagnet

$$v(t) = Ri(t) + L\frac{di(t)}{dt}$$

$$m\frac{d^2y(t)}{dt^2} = mg - K\frac{i^2(t)}{y(t)}$$

I/O and State Variables

- We control the voltage v
- Goal is to control distance y

$$\vec{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} i \\ y \\ \dot{y} \end{bmatrix} = \begin{bmatrix} \text{Current} \\ \text{Distance} \\ \text{Velocity} \end{bmatrix}$$

Linearization about the Equilibrium

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} \frac{u(t) - Rx_1(t)}{L} \\ x_3(t) \\ -\frac{Kx_1^2(t)}{mx_2(t)} + g \end{bmatrix}$$

$$A = \frac{\partial h}{\partial x} = \begin{bmatrix} -\frac{R}{L} & 0 & 0 \\ 0 & 0 & 1 \\ -\frac{2Kx_1(t)}{mx_2(t)} & \frac{K}{m}(\frac{x_1(t)}{x_2(t)})^2 & 0 \end{bmatrix} = \begin{bmatrix} -\frac{R}{L} & 0 & 0 \\ 0 & 0 & 1 \\ -\frac{2Kx_{01}}{mx_{02}} & \frac{K}{m}(\frac{x_{01}}{x_{02}})^2 & 0 \end{bmatrix}$$

$$B = \frac{\partial h}{\partial u} = \begin{bmatrix} \frac{1}{L} \\ 0 \\ 0 \end{bmatrix} \qquad C = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} \qquad D = \begin{bmatrix} 0 \end{bmatrix}$$

$$v_0 = 7 \qquad x_0 = \begin{bmatrix} 7 \\ .00998 \\ 0 \end{bmatrix} \qquad A = \begin{bmatrix} -100 & 0 & 0 \\ 0 & 0 & 1 \\ -2.803 & 982 & 0 \end{bmatrix}$$

References

1. http://ctms.engin.umich.edu/CTMS/index.php?example=Introduction&section=ControlStateSpace
2. https://elec3004.uqcloud.net/laboratories/LeviLab/Levitating%20Magnet%20Modelling%20Example.pdf