CMP755 - Robotics - 2021

Homework #4

Due: 30.11.2021

You can submit your files as softcopy (scans, readable proper images, etc.) or bring as hardcopies to the class.

1. (10 pts) Find the inertia tensor of a cylinder of homogeneous density with respect to a frame attached to the origin at the center of mass of the body. Take the radius as R and height as H.
2. (10 pts) How many memory locations would be required to store the dynamic equations of a general three-link manipulator in a table? Quantize each joint's position, velocity, and acceleration into 24 ranges. Make any assumptions needed.
3. (20 pts)

6.12 [20] The single-degree-of-freedom "manipulator" in Fig. 6.9 has total mass $m = 1$, with the center of mass at

$$^{1}P_C = \begin{bmatrix} 2 \\ 0 \\ 0 \end{bmatrix},$$

and has inertia tensor

$$^{C}I_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 2 \end{bmatrix}.$$

From rest at $t = 0$, the joint angle θ_1 moves in accordance with the time function

$$\theta_1(t) = bt + ct^2$$

in radians. Give the angular acceleration of the link and the linear acceleration of the center of mass in terms of frame {1} as a function of t.

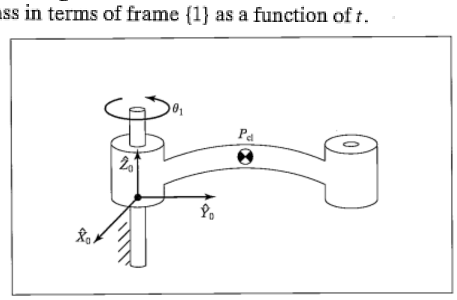

FIGURE 6.9: One-link "manipulator" of Exercise 6.12.

4. (10 pts) A single-link robot with a rotary joint is motionless at $\theta = -5^o$. It is desired to move the joint in a smooth manner to $\theta = 80^o$ in 4 seconds. Find the coefficients of a cubic which accomplishes this motion and brings the arm to rest at the goal. Plot the position, velocity, and acceleration of the joint as a function of time. You can use matplotlib. Code is not necessary.

5. (20 pts) Sketch graphs of position, velocity, and acceleration for a two-segment spline where each segment is a cubic, using the coefficients as given in (7.11). Sketch them for a joint where $\theta_0 = 5.0^o$ for the initial point, $\theta_v = 15.0^o$ is a via point, and $\theta_g = 40.0^o$ is the goal point. Assume that each segment has a duration of 1.0 second and that the velocity at the via point is to be 17.5 degrees/second.

$$\begin{aligned} a_0 &= \theta_0, \\ a_1 &= \dot{\theta}_0, \\ a_2 &= \frac{3}{t_f^2}(\theta_f - \theta_0) - \frac{2}{t_f}\dot{\theta}_0 - \frac{1}{t_f}\dot{\theta}_f, \\ a_3 &= -\frac{2}{t_f^3}(\theta_f - \theta_0) + \frac{1}{t_f^2}(\dot{\theta}_f + \dot{\theta}_0). \end{aligned} \tag{7.11}$$

6. (10 pts) Compute the motion of the system in Fig. 9.2 if parameter values are in m = 2, b = 6, and k = 4 and the block (initially at rest) is released from the position x = 1. Also, plot the response of the distance x(t) wrt t.

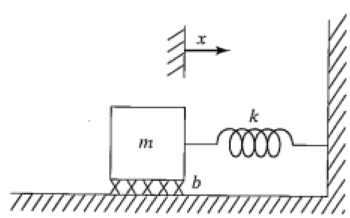

FIGURE 9.2: Spring–mass system with friction.

7. (20 pts) Consider the system of Fig. 9.6 with the parameter values m = 1, b = 4, and k = 5. The system is also known to possess an unmodeled resonance at and that will critically damp $w_{res} = 6.0$ radians/second. Determine the gains the system with as high a stiffness as is reasonable.

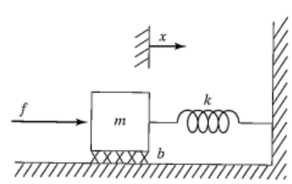

FIGURE 9.6: A damped spring–mass system with an actuator.