Dynamics and Control of Robot-Environment Interaction
(HW 05 Fall 2021)

Due to November 25th, 2021

Problem 5 Control in Task Space (30)

- ✓ Consider a 7dof manipulator, which model is given in class. Implement the following controllers in Joint Space.
- ✓ For each problem choose proper gain.
- ✓ Desired position, x_d, is expressed in base frame.

1. Design and Implement a PD controller with dynamic compensation. Design the controller to have $w_n = 20$ rad/sec and critically damped.

$$\tau = J^T \Lambda F_0^\star + [I - J^T \overline{J}^T]\tau_0 + G, \quad F_0^\star = [F^{\star T}\, M^{\star T}]^T \tag{1}$$

$$F^\star = k_p(x_d - x) + k_v(\dot{x}_d - \dot{x}) \tag{2}$$

$$M^\star = -k_p \delta\Phi - k_v \omega \tag{3}$$

$$\tau_0 = A\{k_p(q_i - q) - k_v \dot{q}\} \tag{4}$$

   - Move the robot to the configuration of $q_i = [0\,0\,0\,{-90^\circ}\,0\,90^\circ\,0]^T$ using the Joint Space Controller (the PD controller with dynamic compensation). Command the end-effector a step of $2cm$ in the y_0 direction. Simultaneously, maintain the initial orientaion of end-effector. Plot the response of the end-effector.
   - Move the robot to the configuration of $q_i = [0\,0\,0\,{-90^\circ}\,0\,90^\circ\,0]^T$ using the Joint Space Controller (the PD controller with dynamic compensation). Command the end-effector to move $10cm$ in the y_0 direction using a cubic spline trajectory. Simultaneously, maintain the initial orientaion of end-effector. Plot the response of the end-effector.

2. Design and Implement Velocity saturation controller.

$$\tau = J^T \Lambda F_0^\star + [I - J^T \overline{J}^T]\tau_0 + G, \quad F_0^\star = [F^{\star T}\, M^{\star T}]^T \tag{5}$$

$$F^\star = k_v(\dot{x}_d - \dot{x}). \quad \dot{x}_d = \begin{cases} \frac{k_p}{k_v}(x_d - x) & |\frac{k_p}{k_v}(x_d - x)| < |\dot{x}_{max}| \\ \frac{|\dot{x}_{max}|}{|x_d - x|}(x_d - x) & |\frac{k_p}{k_v}(x_d - x)| \geq |\dot{x}_{max}| \end{cases} \tag{6}$$

$$M^\star = -k_p \delta\Phi - k_v \omega \tag{7}$$

$$\tau_0 = A\{k_p(q_i - q) - k_v \dot{q}\} \tag{8}$$

   - Move the robot to the configuration of $q_i = [0\,{-60^\circ}\,0\,{-90^\circ}\,0\,30^\circ\,0]^T$ using the Joint Space Controller (the PD controller with dynamic compensation). Command the end-effector to move to $x_d = [0.3\ -0.012\,0.52]^T$ maintaining the initial orientaion of end-effector. Use $\dot{x}_{max} = 0.3$, and choose proper gains. Plot the response of the end-effector.