EML 6351 Spring 2020

Simulation Project 5 - Due March 24 by Midnight.

Instructions:

For this simulation project collaboration with colleagues and any available resource is encouraged. However, any sharing of electronic files with any other individual is considered a violation of the honor code. You may use any simulation software you desire, but Matlab is highly recommended. You are expected to turn in (on-line only) a zipped file containing a written report, which includes all plots and mathematical derivations. You are also required to provide an executable code (meaning a *.m file, Simulink file or other file that can be examined to validate that the results from your report match your simulation code).

Model:

For this simulation project, use the model of a two-link rigid revolute robot manipulator given by

$$\begin{bmatrix}\tau_1\\ \tau_2\end{bmatrix} = \begin{bmatrix} p_1 + 2p_3c_2 & p_2 + p_3c_2 \\ p_2 + p_3c_2 & p_2 \end{bmatrix}\begin{bmatrix}\ddot{q}_1\\ \ddot{q}_2\end{bmatrix} + \begin{bmatrix} -p_3s_2\dot{q}_2 & -p_3s_2\left(\dot{q}_1 + \dot{q}_2\right) \\ p_3s_2\dot{q}_1 & 0 \end{bmatrix}\begin{bmatrix}\dot{q}_1\\ \dot{q}_2\end{bmatrix}$$

$$+ \begin{bmatrix} f_{d1} & 0 \\ 0 & f_{d2} \end{bmatrix}\begin{bmatrix}\dot{q}_1\\ \dot{q}_2\end{bmatrix} + \begin{bmatrix} f_{s1} & 0 \\ 0 & f_{s2} \end{bmatrix}\begin{bmatrix} sgn(\dot{q}_1)\\ sgn(\dot{q}_2)\end{bmatrix} \tag{1}$$

where $p_1, p_2, p_3, f_{d1}, f_{d2}, f_{s1}, f_{s2}$ are unknown positive scalar constants (obviously the simulation file has known values for these parameters, but they can not be used in the controller/adaptation law), $s_2 = sin(q_2),\ c_2 = cos(q_2)$, $\tau_1(t)$ and $\tau_2(t)$ denote the control torque inputs on the first and second joint respectively, and $q(t)$, $\dot{q}(t)$, $\ddot{q}(t)$ represent the angular position, velocity and acceleration of the about the joints of the robot, respectively, where the subscripts denote which joint. Let the coefficients of static friction be $f_{s1}1.2,\ f_{s2} = 0.4$. For this simulation, only $q(t)$ and $\dot{q}(t)$ are assumed to be measurable. For this simulation, use the following desired trajectory

$$\begin{aligned} q_{d1} &= cos(0.5t) \\ q_{d2} &= 2cos(t). \end{aligned}$$

Assignment:

1. (5 points) Implement a standard gradient based adaptive update law, including the aditional static friction terms. Turn in the code in such a manner that it can be implemented/verified that your simulation produces these results.

2. (45 points) Implement a repetitive learning controller (with saturations as decribed in class) for the dynamics except the static friction terms. For the static friction terms use a standard adaptive control element. Turn in the code in such a manner that it can be implemented/verified that your simulation produces these results.

3. (50 points) Provide a typed report that covers the following sections.

   (a) Simulation section including (FOR EACH CONTROLLER):

      1. List control gains used and their values
      2. Tracking error plot for each link
      3. Control input plot for each link (link 1 max torque is 250Nm, link 2 is 30Nm)
      4. Plot of the adaptive estimates
      5. Plot of the repetitive learning term, $\hat{w}(t)$.
      6. Plot of the parameter estimate errors (i.e., $\widetilde{\theta}(t)$)

   (b) Discussion section that describes the following points:

      1. Differences in tuning the control gains/adaptation gains between the standard adaptive and RLC
      2. Performance of the tracking error for each controller
      3. Performance of the adaptation for each case
      4. For the above three discussion topics, be sure to compare and contrast the different results.