EML 6351 Spring 2020

Simulation Project 1

Due Jan 30th 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. A text file (*.m) is provided in the files section of the class Canvas page that contains the dynamic model. This assignment is due based on the dates given in the assignment section. You are expected to turn in (on-line only) a zipped file containing a typed 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 (see Canvas for the *.m file)

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

$$+ \begin{bmatrix} f_{d1} & 0 \\ 0 & f_{d2} \end{bmatrix} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix} \tag{1}$$

where $p_1, p_2, p_3, f_{d1}, f_{d2}$ 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. For this simulation, only $q(t)$ and $\dot{q}(t)$ are assumed to be measurable. For this simulation, use the following desired trajectory

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

In your code, you will get better results if you analytically calculate the derivatives of the desired trajectory and type them in, rather than use the simulation numerical methods to take the derivative for you.

Assignment:

1. (10 points) For the given model, type a report that shows the steps to derive the filtered torque $\tau_f(t)$, the filtered regression matrix $Y_f(t)$, and the filtered desired regression matrix $Y_{df}(t)$. Specifically, your end result will be the explicit (in terms of each element) vectors/matrices that would need to be typed into a program to be numerically solved, justified by the derivation.

2. (45 points) Derive and simulate the following controllers
   (a) Traditional adaptive controller with gradient adaptive update law
   (b) Composite adaptive controller with gradient adaptive update law
   (c) Composite adaptive controller with least squares adaptive update law
   (d) For the above simulations, turn in the code in such a manner that it can be implemented/verified that your simulation produces these results.

3. (45 points) Provide a typed report that includes the following sections:
   (a) Dynamic model
   (b) Problem definition and open-loop error system development
   (c) Control design (including adaptive update law) and closed-loop error system development
   (d) Stability analysis of each controller
   (e) 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 parameter estimate errors (i.e., $\widetilde{\theta}(t)$)
   (f) Discussion section that describes the following points:
      1. Differences in tuning the control gains/adaptation gains
      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.