Intro to Robot Control – Spring 2021

Problem Set #7: Robust and Adaptive Control

The goal of this assignment is to test the robustness of the controllers you designed in PS#6, and to design and simulate robust and adaptive controllers that are capable of dealing with model uncertainty/disturbances. We will again base our simulations on the Quanser 2-DOF serial robot, using the same dynamic model, parameter values, and desired trajectory that from PS#6.

You will not need a new Simulink template for this assignment. For the sliding mode controller, you can simply build onto your inverse dynamics controller from PS#6. For the adaptive controller, you can alter your feedforward controller from PS#6, or it may be easier to simply start fresh from the PS#5 template.

1. Implement a **sliding mode control** action on top of your inverse dynamics control and experimentally tune your sliding mode parameters to optimize the tracking performance at low speed (f=0.2 circles/s) and high speed (f=1 circles/s). Compare the tracking performance of your sliding mode controller to the controllers you implemented in PS#6.

2. Now **test the robustness** of your previously designed controllers by introducing the following two "disturbances" into your dynamics: (A) Increase the true mass of link 2 by 50% (B) Multiply the true coulomb friction in both joints by a factor of 10. Make these changes to the "true" parameter values in the *Forward Dynamics* block inside your *Manipulator* subsystem, but do not change the "modeled" parameter values that you use in your compensators. Implement these "disturbances" independently and compare the robustness of the following controllers at high speed (f=1 circles/s):
    2.1 PD Control with feedforward compensation (from PS#6)
    2.2 PD Control with inverse dynamics control (from PS#6)
    2.3 PD Control with inverse dynamics control and sliding mode control (from part 1)

3. **GRADS ONLY:** *(Required for 6000 level students only)* Remove the disturbances from the previous problem (undo any changes you made to the *Forward Dynamics* block), but now assume that all the mass/inertia parameter values are unknown to your controller. Construct and simulate an **adaptive controller** at high speed ((f=1 circles/s). Does the tracking error converge to zero? Do the mass/inertia parameters converge to their true values?

Note: For each **NEW** control scheme in this assignment, provide an image of your Simulink model and printouts of your Embedded MATLAB Functions. For each simulation, send the x-y and joint data to the workspace and make a plot of the x-y trajectory (plot the actual trajectory overtop of the desired trajectory), and a plot of the joint angle errors. In the case of the adaptive controller, also plot your parameter estimates vs. time. Be sure to properly title your plots and label your axes. When comparing the tracking performance of different controllers, you may want to use both peak joint errors and the RMS (Root-Mean-Square) of the joint errors as metrics. For a fair comparison, be sure you use the same simulation configuration (solver, step time, time duration).