ME EN 5230/6230, CS 6330, ECE 6651

Intro to Robot Control – Spring 2023

Problem Set #6: Robust and Adaptive Control

The goal of this assignment is to test the robustness of the controllers you designed in PS#5, 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#5.

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#5. For the adaptive controller, you can alter your feedforward controller from PS#5, 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#5)
   - **2.2** PD Control with inverse dynamics control (from PS#5)
   - **2.3** PD Control with inverse dynamics control and sliding mode control (from part 1)

3. **<u>GRADS ONLY:</u>** *(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 <u>label your axes</u>. 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).