ME EN 5230/6230, CS 6330

Intro to Robot Control – Spring 2021

LAB ASSIGNMENT #5: HYBRID POSITION/FORCE CONTROL

Introduction

The purpose of this assignment is to implement **hybrid position/force control** in **operational space** using the Quanser 2-DOF serial robots. The robot should be oriented on the desk in the same configuration as in Lab 4, and the same lab protocols (including homing) will be used. The robot will again be interacting with the benchtop, however this time we will use a combination of position and direct force control to maintain a desired force while stroking along the benchtop as in PS#10. We will use the same force sensor as in Lab 4 to measure the contact forces between the robot and the benchtop. Please observe the same care for the force sensors as instructed in Lab 4.

Lab Exercises

On Canvas, you are provided with a Simulink Template <Lab5_template2021.slx>. The gravity compensator again includes the mass of the force sensor, and the forward kinematics have again been adjusted to increase the length of link 2. Since we will only be using quasi-static/slow trajectories in this lab exercise, gravity compensation is sufficient (full inverse dynamics control should not be necessary). The force sensing subsystem is the same as in Lab 4.

Note that the operational space portion of the control has been divided into two phases. During Phase 1, we will control position in both x and y directions in order to smoothly bring the robot into contact with the benchtop. Phase 1 control has already been implemented for you and uses the same operational space control as in Lab 4. After two seconds, the control will switch to Phase 2, in which you can now implement hybrid position/force control. Your task will be to design and simulate a series of controllers for Phase 2 in order to stroke the benchtop with a desired force of -1 N.

Modify the Phase 2 subsystem to implement the following control schemes:

1. Hybrid Position/Force Control with P force control
2. Hybrid Position/Force Control with PI force control

In each of these cases, you should also have a proportional gain on the position error, and use an inner velocity loop to add damping (instead of derivative control).

For each of the above control schemes, simulate first with a quasi-static trajectory (speed = 0 strokes/sec) and then with a slow trajectory (0.2 strokes/sec). You will find that with the quasi-static trajectory, the force gains are easier to tune and you should be able to get very good force tracking. When the robot is stroking along the benchtop, the stick/slip frictional behavior causes significant disturbances that makes it extremely difficult to achieve smooth force tracking. If you like, you can try putting something smooth (like a sheet of paper) between the robot and the benchtop. You can also try changing the magnitude of the desired force (smaller y-forces result in less frictional disturbances). Compare the stability and force/position tracking performance of each control scheme for both 0 strokes/sec and 0.2 strokes/sec.

Note: Plot the x-position and tracking error vs. time, and the y-force vs. time (for reference, plot the actual trajectories overtop of the desired trajectories). Be sure to properly title your plots and label your axes. For each controller, provide an image of your Simulink model (in this case the Phase 2 subsystem) and printouts of any new Embedded MATLAB Functions. Be sure to properly title your plots and label your axes. If you wish you can use the *Robot GUI* that is posted on Canvas to control the experiments. However the GUI does not account for the increase in length of link 2, and the trajectory drawn on the GUI will not be representative of the actual end-effector trajectory.