ME EN 5230/6230, CS 6330, ECE 6651

Intro to Robot Control – Spring 2023

Problem Set #8: Indirect Force Control

For this assignment you will design and simulate force controllers for the same planar 2-DOF robot used in previous assignments. This time, the robot is to interact with a horizontal wall at y = -0.025m, having a stiffness k_w and damping b_w. On the course website, you are provided with a Simulink template <PS8_template2023.slx>, which has PD control already implemented in operational space (using Jacobian Transpose control). The wall dynamics are included in the robot/environment subsystem. Using this template, you will experiment with several methods for indirect force control. All controllers will be implemented in operational space (rather than joint space). Note that the motor and amp gains have already been compensated for in the robot/environment subsystem, such that it takes in a commanded motor torque.

The general idea of indirect force control is to control the end-effector position, but make it sensitive to external force. The desired trajectory for the robot is programmed in Cartesian coordinates:

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0.075\cos(2\pi f t) + 0.2 \\ 0.075\sin(2\pi f t) - 0.025 \end{bmatrix}$$

This creates a circular trajectory centered at [x,y]=[0.2m,-0.025m] with a radius of 0.075m, which will result in the robot hitting the wall during a portion of the trajectory. Your task is to design and simulate a series of indirect force controllers in operational space, such that the force on the wall is limited to 3 N when using a relatively slow speed of 0.2 circles/sec. Start by using the Jacobian Transpose control in operational space, and soften the PD gains in the y-direction (this is basic stiffness/damping control). Proceed to implement controllers for each of the following:

1. Stiffness/Damping Control
2. Full Impedance Control with Stiffness/Damping/Inertia
3. Compliance Control (with Inverse Dynamics Control)
4. Full Admittance Control with Stiffness/Damping/Inertia

For each control scheme, simulate with a soft wall (k_w = 1 N/mm) and a hard wall (k_w = 10 N/mm) at 0.2 circles/sec. In each case, try to find a set of impedance/admittance parameters that limits the magnitude of the external force to less than 3 N. For some of these controllers, you may not be able to get the initial impact force to be less than 3 N, which is to be expected. Keep an eye on the motor current commands. Motor saturation may limit your ability to reduce the initial impact force when the robot comes into contact with the wall. In this case, you can temporarily remove the saturation block in the robot subsystem to see if that allows you to reduce the simulated impact force any further.

For each control scheme, provide an image of your Simulink model. For each simulation, send the x-y and force 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 external force vs. time. Be sure to properly title your plots and label your axes. Comment on the pros and cons of each control scheme (e.g. compare tracking performance in free space, ability to limit force during wall contact, stability during wall contact, sensor requirements, etc). If you wish, you can control your simulations with the *RobotApp*, which has an option to display the wall and modify the wall stiffness.