16-662A: Robot Autonomy
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HW1: Kinematics & Control

Control

A screenshot of the force plots for the case where the whiteboard is static. Plot the outputs of the force controller and impedance controller superimposed on each other on the same figure. Make sure to include a title, axis labels and a legend identifying which curve indicates which corresponding controller.

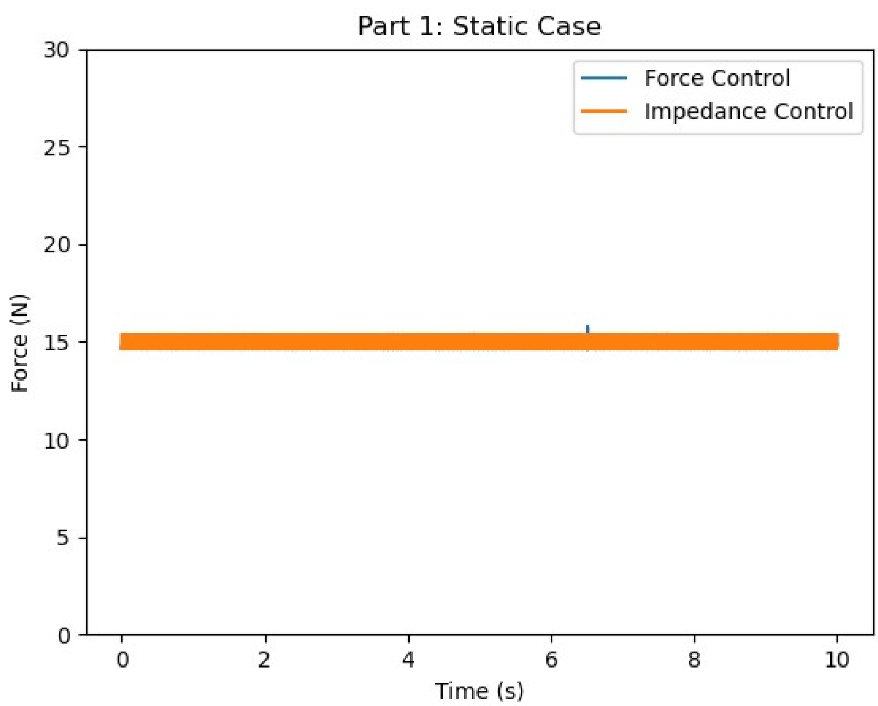

Fig 1. *Force over time for the static whiteboard case for both force controller and impedance controller*

A screenshot of the force plots for the case where the whiteboard is oscillating. Plot the outputs of the force controller and impedance controller superimposed on each other on the same figure. Make sure to include a title, axis labels and a legend identifying which curve indicates which corresponding controller.

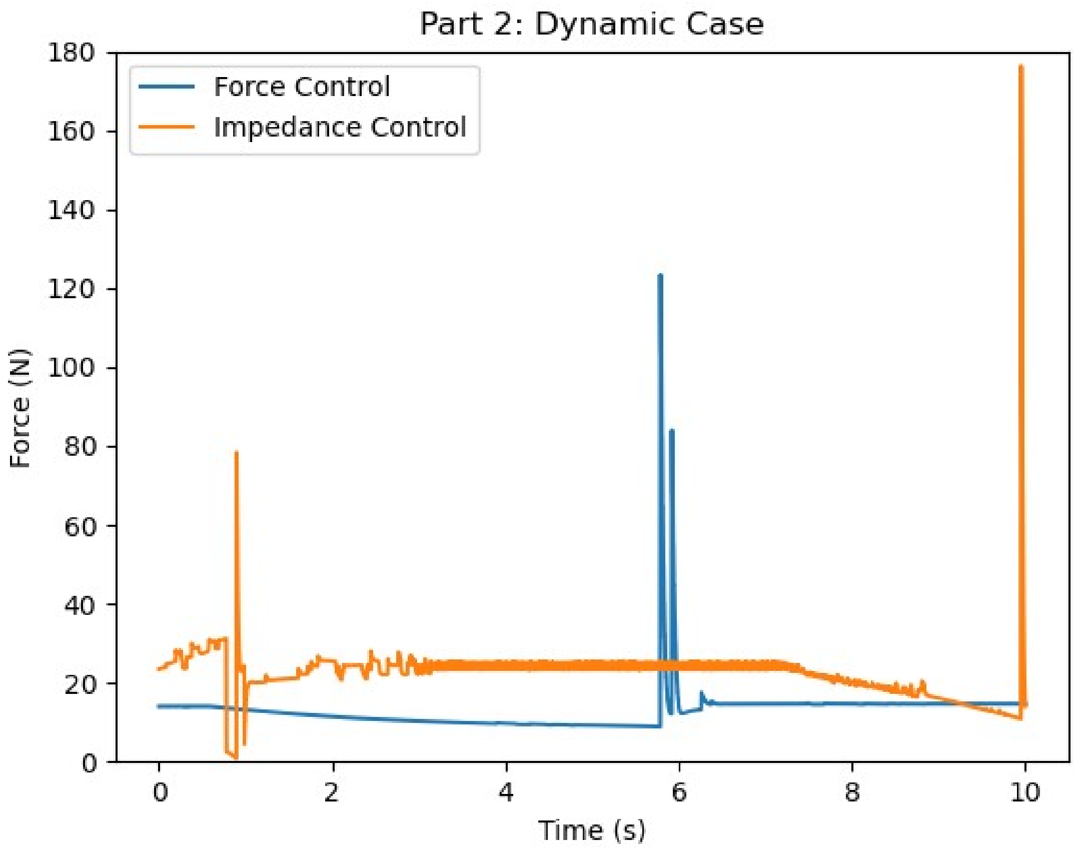

Fig 2. *Force over time for the dynamic whiteboard case for both force controller and impedance controller*

A screenshot of the robot when the board is near its maximum amplitude, i.e. closest to the robot.

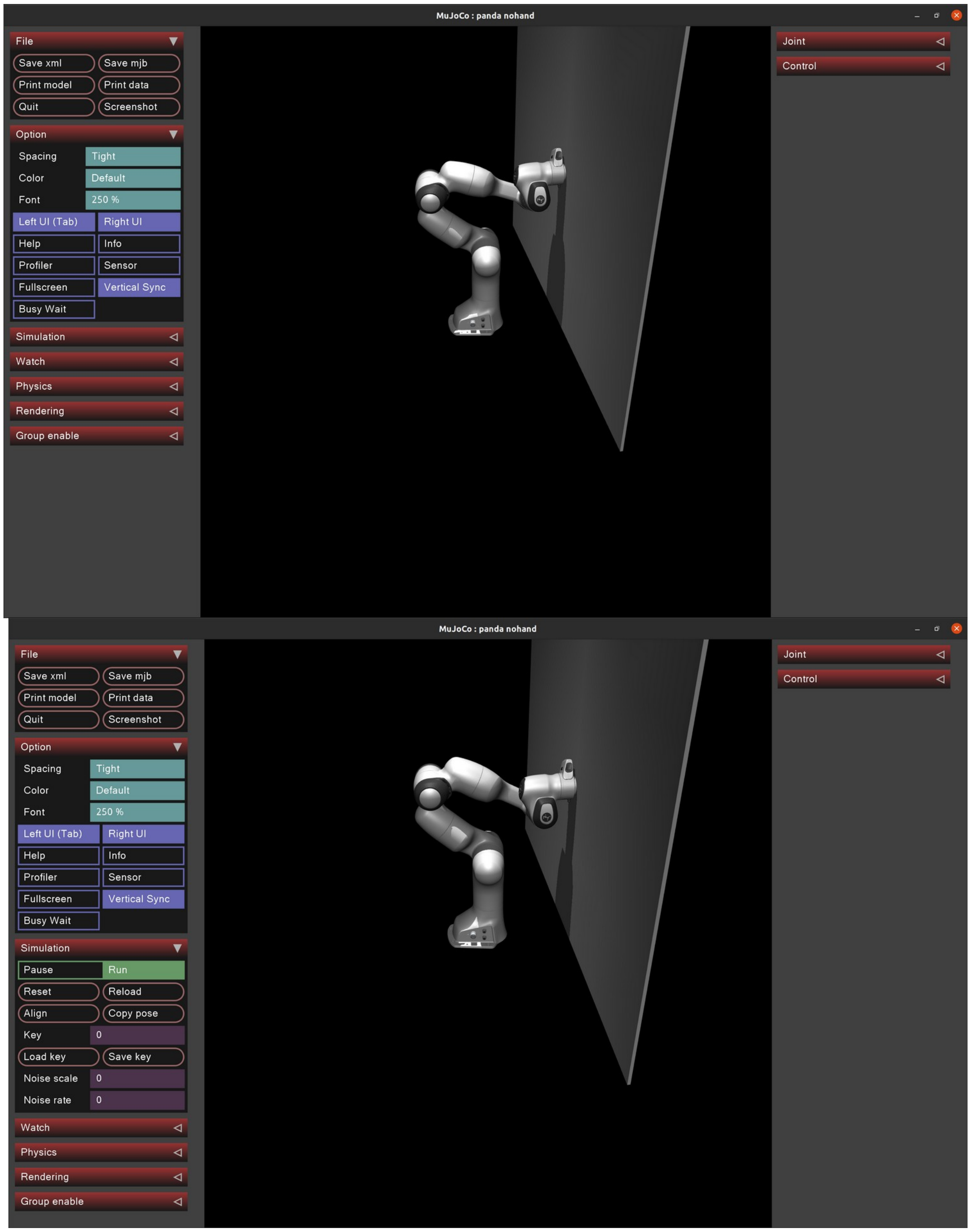

Fig 3. *Mujoco simulation for when the whiteboard is closest to the robot for both force (top) and impedance control (bottom).*

A 2-3 sentence explanation of the differences in the behavior of the force and impedance controllers.

For the static case, both impedance and force controllers behaved in a stable manner. However, once subjected to the static case, the impedance controller was unable to maintain the 15 N force. When the board moved closer to the arm, the force applied by the arm was much higher. The impedance controller acted like a virtual spring, applying more energy the closer the board moved.

Kinematics

The 3 end effector poses (in matrix form) corresponding to q1 , q2 , and q3 .

Q1:

Joints:

[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]

computed FK ee position

[8.80000000e-02 -8.93992163e-18 9.26000000e-01]

computed FK ee rotation

[[1.0000000e+00 0.0000000e+00 0.0000000e+00]

 [0.0000000e+00 -1.0000000e+00 -1.2246468e-16]

 [0.0000000e+00 1.2246468e-16 -1.0000000e+00]]

Q2:

Joints:

[0, 0, -0.7853981633974483, -0.2617993877991494, 0.3490658503988659, 0.2617993877991494, -1.3089969389957472]

computed FK ee position

[0.15710277 -0.10259332 0.93602711]

computed FK ee rotation

[[0.64935398 0.75871099 0.05193309]

 [0.7552124 -0.65137389 0.07325497]

 [0.08940721 -0.00834789 -0.99596017]]

Q3:

Joints:

[0, 0, 0.5235987755982988, -1.0471975511965976, -1.1344640137963142, 0.7853981633974483, 0.0]

computed FK ee position:

[0.40136375 0.08742801 0.85526363]

computed FK ee rotation

[[0.98015816 -0.18113365 -0.08050201]
 [-0.17410263 -0.5925751 -0.78647507]
 [0.09475362 0.78488557 -0.61235316]]

The final joint angles for moving to the end effector goal pose of R

Error 8.370645473667519e-07 0.0004986687811625232

****Computed IK angles**

[0.5011886887083558, 0.29523100193388135, -0.5896059193605828, -2.080071658114002, -0.09679252763855935, 3.9118547902983285, -2.9090877932125014]

computed FK ee position

[6.00000133e-01 -1.55347259e-07 4.99999961e-01]

computed FK ee rotation

[[-5.77829327e-07 -9.10697616e-05 9.99999996e-01]

[5.82155730e-05 9.99999994e-01 9.10697951e-05]

[-9.99999998e-01 5.82156253e-05 -5.72527645e-07]]

Use the position controller callback and move the robot to the joint position that the inverse kinematics returns. Include an image of the robot at this position.

Fig 3. *Mujoco simulation of the position controller tracking the **desired position obtained from the damped-least squares inverse kinematics.*

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