16-662A Robot Autonomy: Homework 1 (Spring 2023)
Kinematics and Controls

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3. PID Control

3.1 Part 1

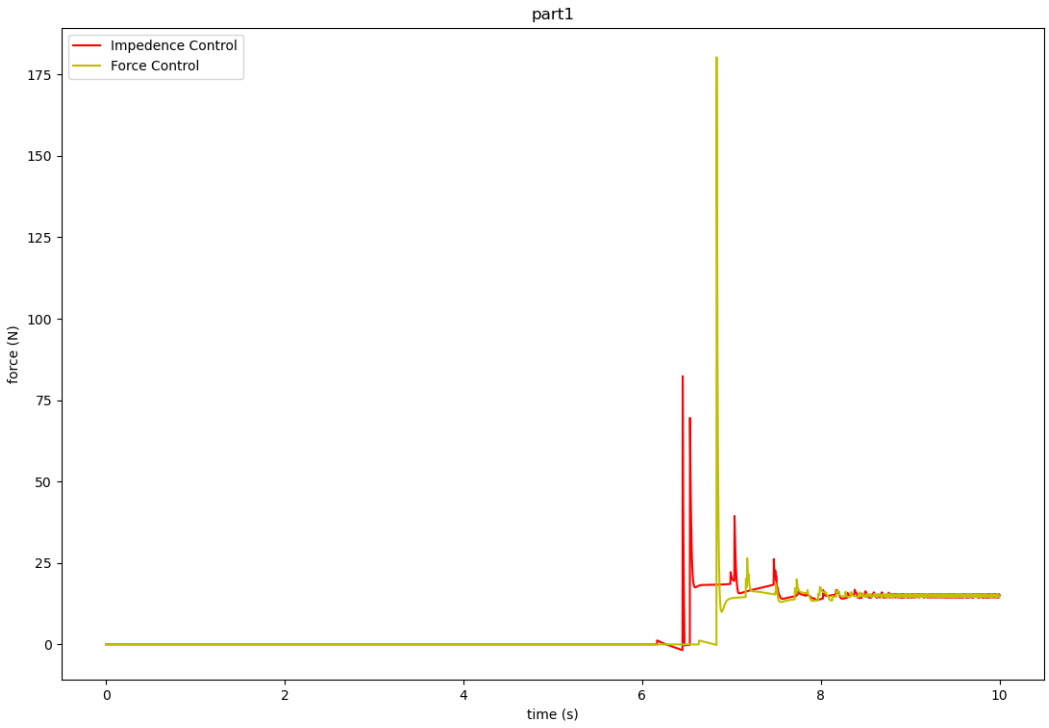

Figure 1: Force Control and Impedance Control for Static Board

3.1 Part 2

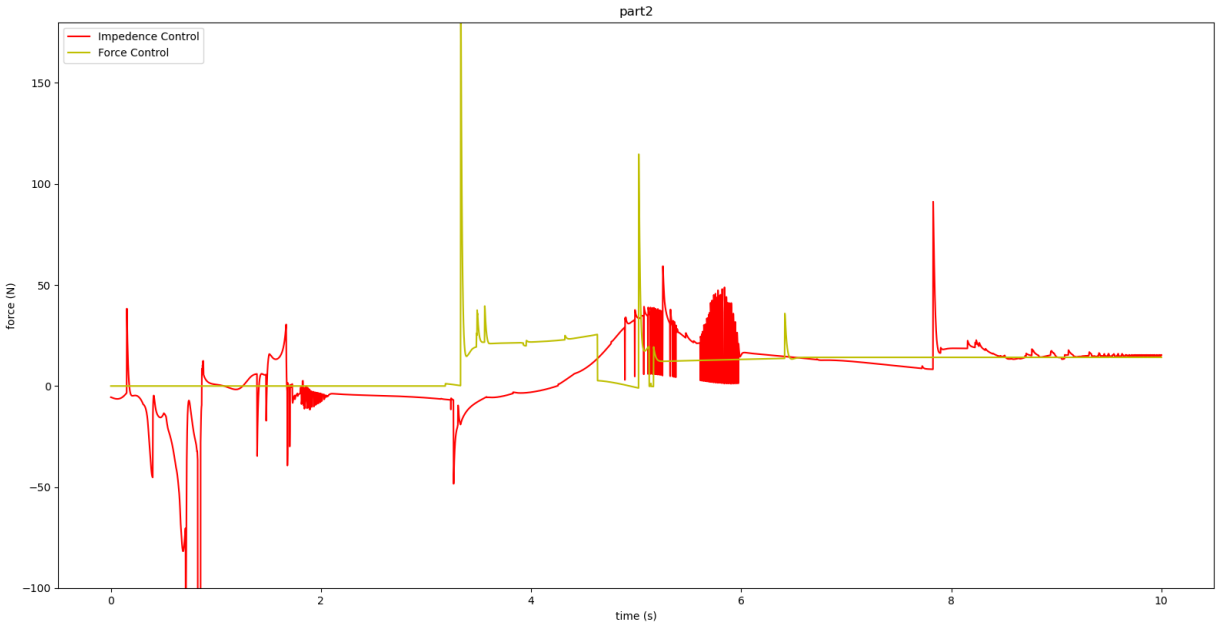

Figure 2: Force Control and Impedance Control for Oscillating Board

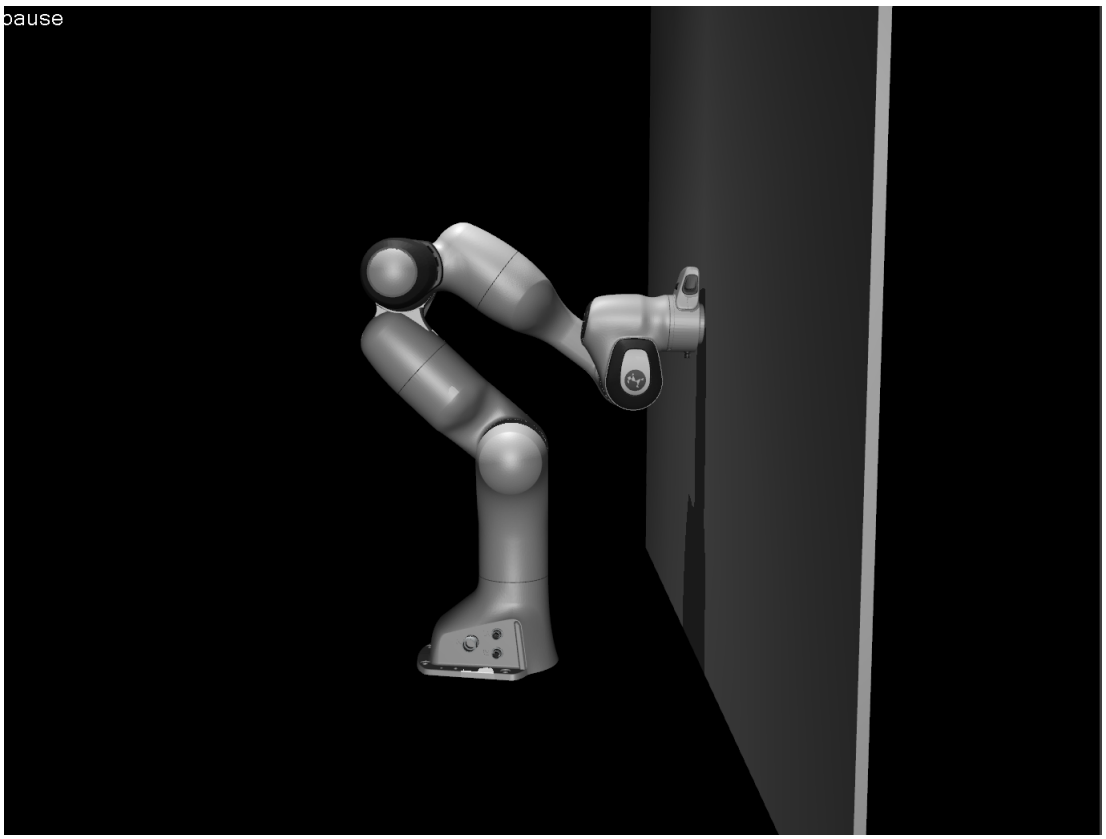

Figure 3: Simulation of Robot with Oscillating board (at max amplitude)

Observed Differences Between Force Control and Impedance Control

From the Fig 1 one can see that force control (in yellow) causes larger spikes when the end-effector contacts the board. Impedance control can however be tuned to give only the required amount of force and is smoother to converge.

4. Kinematics

4.1 Forward Kinematics

The target angles for each joint was specified in three different configurations:

- q1 = $[0°, 0°, 0°, 0°, 0°, 0°, 0°]$
- q2 = $[0°, 0°, -45°, -15°, 20°, 15°, -75°]$
- q3 = $[0°, 0°, 30°, -60°, -65°, 45°, 0°]$

The respective end-effector poses for each above target was:

- q1

$$t = \begin{bmatrix} 0.088 \\ 0 \\ 0.926 \end{bmatrix}$$

$$R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & -1.224 \\ 0 & 1.224 & -1 \end{bmatrix}$$

- q2

$$t = \begin{bmatrix} 0.1571 \\ -0.1025 \\ 0.9360 \end{bmatrix}$$

$$R = \begin{bmatrix} 0.6493 & 0.7587 & 0.0519 \\ 0.7552 & -0.6513 & 0.0732 \\ 0.0894 & -0.0083 & -0.9959 \end{bmatrix}$$

- q2

$$t = \begin{bmatrix} 0.4013 \\ 0.0874 \\ 0.8552 \end{bmatrix}$$

$$R = \begin{bmatrix} 0.9801 & -0.1811 & -0.0805 \\ -0.1741 & -0.5925 & -0.7864 \\ 0.0947 & 0.7848 & -0.6123 \end{bmatrix}$$

4.2 Inverse Kinematics

The robot was initialized to a specific configuration and the following target pose of end-effector was given:

$$t = \begin{bmatrix} 0.6 \\ 0 \\ 0.5 \end{bmatrix}$$

$$R = \begin{bmatrix} 0.0 & 0.0 & 1.0 \\ 0.0 & 1.0 & 0.0 \\ -1.0 & 0.0 & 0.0 \end{bmatrix}$$

After performing inverse kinematics, the final joint angles were recorded below:

$$q = [-0.02605, 0.05772, -0.00797, -2.11344, -0.14733, 3.7117, -0.9441]$$

Position Control After Inverse Kinematics

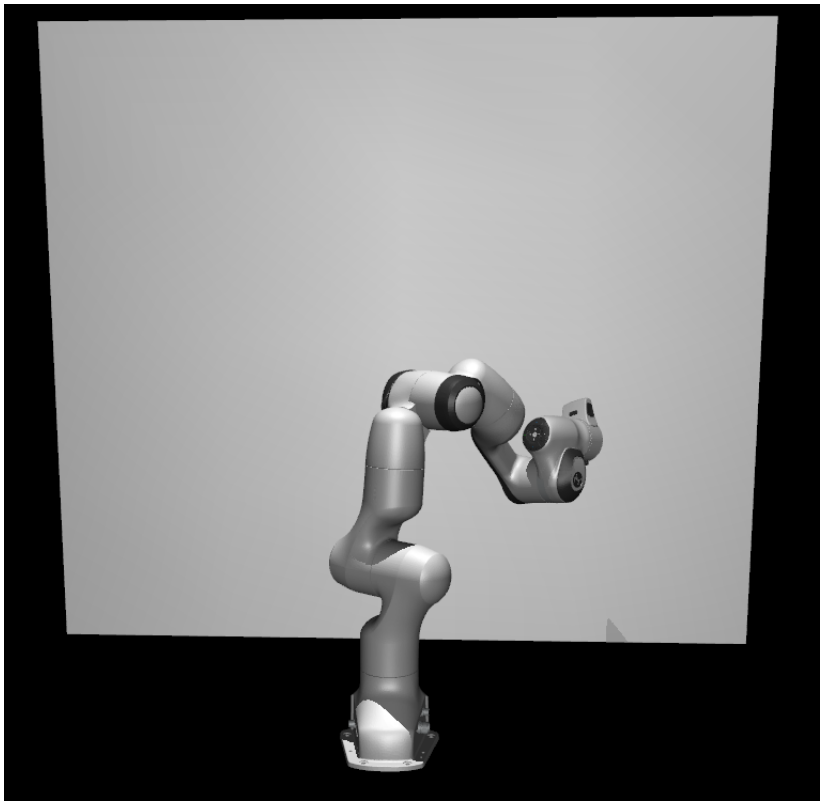

Figure 4: Robot after position control on given joint angles (view 1)

Figure 5: Robot after position control on given joint angles (view 2)