Advanced Robotics
Homework 3: Calibration

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Report

1 Robot model

The main assumptions:

1. Stiffness of all joints - 120.5×10^6 N/m
2. The length of the links: $l_1 = 0.1m$, $l_3 = 0.4m$
3. All the links are considered as rigid
4. Forward kinematics: $H = T_z(l_1)R_z(q_1)T_z(q_2)T_y(q_3)T_y(l_3)$

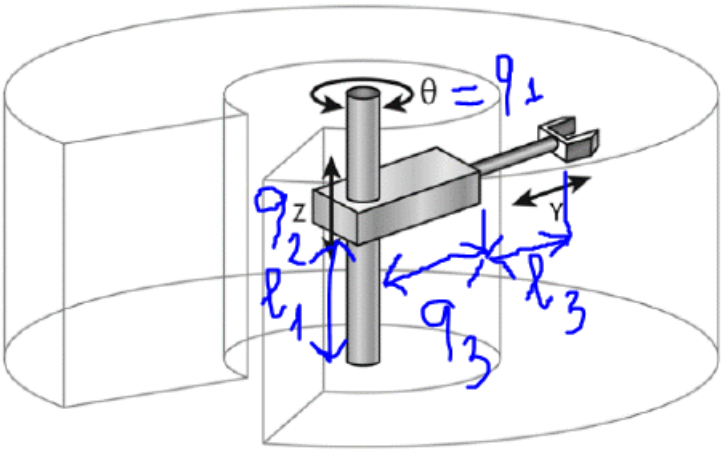

Figure 1: Cylindrical robot

5. Inverse kinematics:

$$q_1 = atan2(y, x) - \pi/2$$

$$q_2 = z - l_1$$

$$q_3 = \sqrt{x^2 + y^2} - l_3$$

6. VJM model (after each actuated joint we add the 1 DoF virtual spring):

$$T_{VJM} = T_z(l_1) \cdot R_z(q_1) \cdot R_z(\theta_1) \cdot T_z(q_2) \cdot T_z(\theta_2) \cdot T_y(q_3) \cdot T_y(\theta_3) \cdot T_y(l_3)$$

2 Estimated and real parameters

The range of the joint variables and wrench:

$q_1 = [-\pi; \pi]$

$q_2 = [0; 1]$

$q_3 = [0; 1]$

$W_i = [-1000, 1000]$, where $i = [1..6]$.

We need to find the desired parameters with the help of matrix A. Using the equations from the slides 20 and 21 of the Lecture 5 (Klimchik A.), we can find the desired parameters ΔX.

A - observation matrix that defines the mapping between the unknown compliances π and the end-effector displacements Δt under the loading $\mathbf{W}$ for the manipulator configuration $\mathbf{q}$.

The total amount of experiments = 30. The configurations and the value of the wrench were chosen randomly. Also we introduce some noise to the computed Δt with zero mean and standard deviation = 10^{-6}.

Original compliance parameters, 10^{-8}	Experimental compliance parameters, 10^{-8}
0.83	0.77
0.83	0.85
0.83	0.79

Table 1: Comparison of compliance parameters

The observation matrices **A** for each experiment are provided in Python Code. The link is in the fifth section.

3 Plots of trajectories before and after the calibration

The trajectory of the robot is presented on the figure 2. Green dots represent the trajectory before calibration, blue - calibrated trajectory, red - desired trajectory.

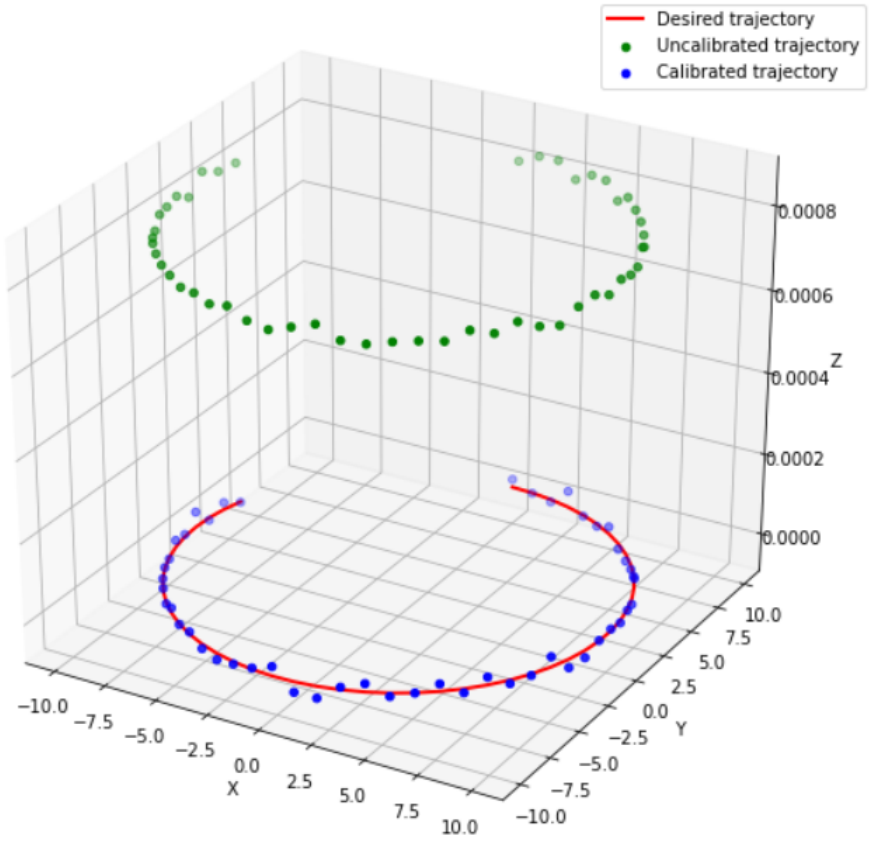

Figure 2: Trajectory of the cylindrical robot before and after the calibration

4 Discussion of the results

All the steps of calibration are performed. The resulting plots show that without calibration the error in motion would be approximately 0.8 mm. Calibration allows to compensate the error successfully.

5 Link to Github

https://github.com/fam-ca/Calibration