ENPM662 - Fall 2022

Homework - 05

Due: 27th November 2022 Points/Weightage: 5 points

Manipulator Dynamics

In Homework - 04, you were tasked with moving the pen mounted on the robot end-effector along a given circular trajectory using position and velocity kinematics. In industrial applications involving grasping and force control, it is important to take into consideration the workspace forces/moments at the tool of the robot and the produced torques at the robot's joints.

As set up previously, the robot's end-effector has a pen (length of 10 cm, see Fig. 1) rigidly mounted on it such that it points along the 'z-axis' of the end-effector frame (Frame {n}). Joint 3 of the robot is locked (**θ_3 = 0**) and cannot move, such that the Jacobian matrix is a square matrix of size 6x6.

In this assignment, your task is to calculate the joint torques that are required to compensate for the robot's weight and ensure the pen is pushed against the wall with a force of 5 N while drawing the circle of **radius 10 cm within 200 seconds**. Assume the robot motion is quasi-static, such that,

```
q_dot ≅ 0, q_ddot ≅ 0
```

Here is a CAD model of the robot which you may use to measure specific lengths if required.

Use the mass information of links of the Panda robot from the franka_panda_decription ROS package URDF/Xacro files (use *panda_arm.xacro* for the links and *hand.xacro* for the gripper). You may also use information from other sources such as the robot's datasheet, technical documentation, or research papers involving the Panda robot. Cite the source(s) used if any.

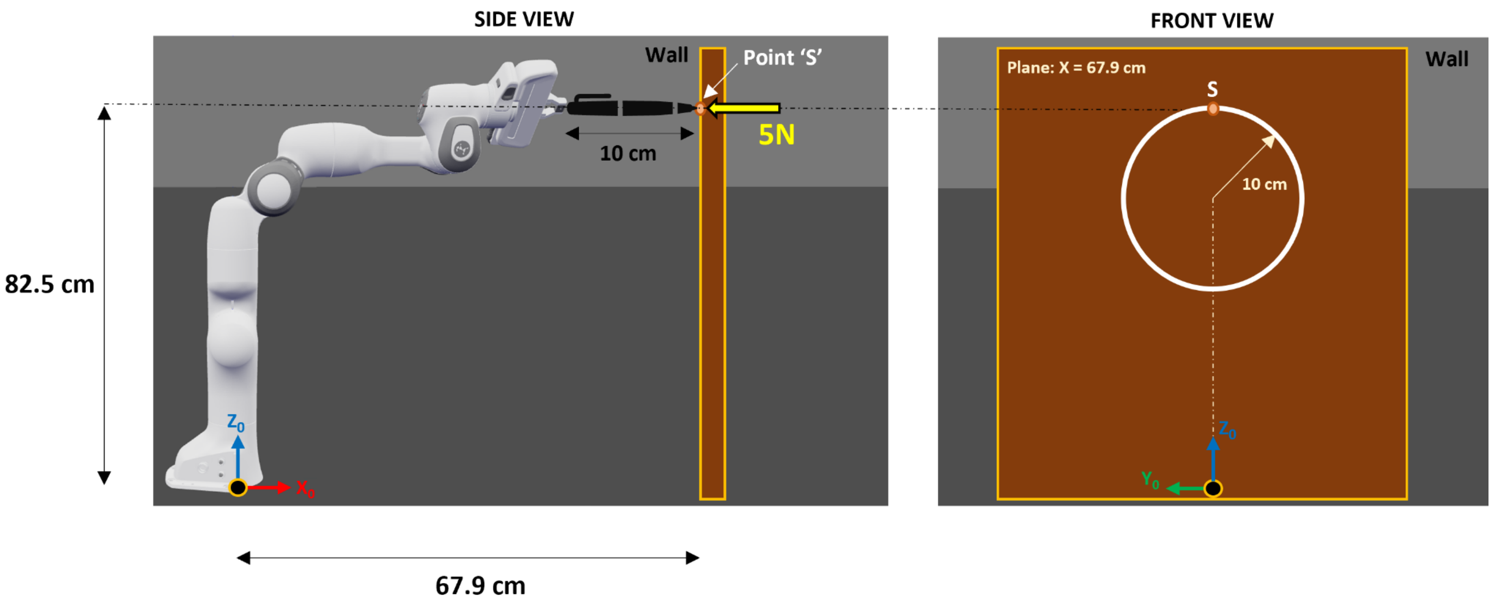

Fig. 1: Panda Robot with the exerted 5N force

NOTE: Reuse code from the previous assignments to set up the Jacobian and Transformation matrices. You may use inbuilt functions that assist you in setting up the Gravity Matrix, such as taking derivatives, computing cross-products, matrix inversion, etc.

Deliverables

- A **PDF** report containing the following.
    - Updated circular trajectory equations for a time duration of 200 seconds.
    - A brief explanation of the steps and equations involved in the computation of the joint torques using the Jacobian matrix and Lagrange equation. Clearly state assumptions, if any.
    - Mention the used masses and/or lengths of the robot links and cite all sources.
    - The **picture of the plot output** of the robot's joint torques between t=0 and t=200 seconds. Plot 6 graphs, one for each joint: 1, 2, 4, 5, 6, and 7.
    - Name your report: ***<your-directoryID>_hw5_report.pdf*** [Note: Directory ID ≠ UID!]
- All **codes** used (Make sure the code(s) submitted run **without any errors**!)
    - The code(s) **must** print the parametric Gravity matrix, *g(q)* to the terminal
    - The code(s) **must** plot the computed joint torques (all 6)

        - Plot the torque value as a series of points. See this link.
        - Plotting the circle is optional.
    - Include a *readme* file that briefly describes **how** to run your code(s) and if **any dependencies** need to be installed. Use **Markdown (`.md`) format**.
- Submit the above in a .zip file with the name: ***<your-directoryID>_hw5.zip***
    - Folder Structure:
        - *<your-directoryID>_hw5.zip / readme.md*
        - *<your-directoryID>_hw5.zip / <your-directoryID>_hw5_report.pdf*
        - *<your-directoryID>_hw5.zip / code —> should contain all codes (.py) used*

Supplementary Material

Robot Dynamics Equation :

$$\mathrm{M(q)\ddot{q} + C(q,\dot{q})\dot{q} + g(q) = \tau + J^T(q)\,F}$$

where,

$$\mathrm{F} = [\mathrm{F}_x, F_y, F_z, T_x, T_y, T_z]^T$$

(end-effector torque components are 0 in our case)

Lagrangian Dynamics:

$$\tau = \frac{d}{dt}\frac{\partial L}{\partial \dot{q}} - \frac{\partial L}{\partial q}$$

where,

L = K - P

K → Kinetic Energy of the system, P → Potential Energy of the system