Assignment 2 (8 Marks)

MCEN90028 Robotics Systems 2021

Due date: As specified on Canvas LMS

1 Overview

This assessment aims to provide you with the practice on (and assess your understanding of) the topics covered in Modules 4 and 5, which build upon the content in Modules 2 (primarily) and 3.

- Before you start, make sure you understand the terms dictating the integrity of your academic work, the Department late submission policies. Given you are in an advanced elective of your Master of Engineering candidature, ignorance is not a valid reason for academic misconducts.
- I will repeat the message that you will be awarded (marks) for the merit of your work. This means that an incorrect answers or badly argued claims do not merit marks. An assessment is not a mechanism where you are entitled to full marks for making no mistakes.

1.1 Objectives

The following are the objectives of this assessment. You are to address these objectives **explicitly**.

1. To demonstrate your proficiency in deriving a Jacobian matrix $J(q)$ for your robot, that maps the joint velocities into the end-effector velocity expressed in a given frame of coordinates.
2. To evaluate whether joint torques required to lift up the inertia of the robot (of your design) in addition to the load (the weight of the (heaviest) chess piece), within all required workspace, evaluated in a quasi static manner, are within the torque range that can be produced by the motors.
3. To train the ability to communicate effectively in written form the purpose and the finding of exercise, as well as the ability to convince the reader of the accuracy of the outcomes. The evaluation of this aspect is implicit in the presentation of your answers to the first three objectives.

Given that this is the second assignment in this subject, relatively less step-by-step guidance is provided on the working and how to present your work coherently, compared to Assignment 1.
Please be reminded again that you are required to write a self-contained report. **It should be an actual report, to be read and understood by a third party outside of this class, not just an answer sheet**.

2 Description of Task

Continuing from Assignment 1, we will develop the building blocks required to control the motion of the robotic manipulator in this subject. As a reminder: you are designing and realising a robot of your own design to move the chess pieces in the project. The chess set is of your choosing, providing a unique dimension to the required workspace for your robot (the robot being designed and built by your group of 3 students), and the robot kinematic parameters were selected based on the necessary reachable workspace in Assignment 1. You are to use the kinematic parameters identified in your answer to the previous assignment.

2.1 Deriving the Jacobian Matrix for the Joint Velocity in Relation to the End-Effector Velocity (up to 3 marks)

1. Present the information pertaining to the kinematics of your robot. Copy the diagram from assignment 1, as well as the final expressions of the forward kinematics. (worth 0 mark in itself but significantly affects the clarity of your presentation)

2. Derive the Jacobian matrix for your robot that relates the translational velocity and the angular velocity of the end-effector frame to the joint velocities. Do this NOT by taking the partial derivative of the forward kinematics expressions with respect to the joint displacements, but by taking the cross product of the rotational axes and the lever arm between the corresponding joints to the end-effector. (up to 2 marks)

3. Justify that your Jacobian is correct. (up to 1 marks)

2.2 Evaluating the joint torque required to overcome gravity associated with the task (up to 5 marks)

1. Derive the Jacobian matrices J_i that relates the joint velocities to the velocities of the centres of mass m_i of links $i = 1, ..N$ (where N is the number of joints or moving links in the robot) (2 marks).

2. Estimate (to your best ability) the mass values of the links m_i of the robot of your design as well as the location of the centre of mass p_{c_i} with respect to the

coordinate frame i that moves with the link i. (Do this in kg as the unit of weight). Estimate the heaviest chess piece that your robot will need to lift. Calculate the torque on all joints $\mathbf{q} = [q_1, q_2, ..q_N]^T$ that would be needed to overcome the gravity component of the task, to account for the robot's own weight and the weight of the chess piece across the necessary workspace Q. Perform this calculation across the workspace of the robot using for loop similar to that in Assignment 1. Find the maximum torque needed for each individual joint across the entire workspace. Take note on whether this required torque is larger than the nominal torque of your given motors (if yes, you need to revisit your design to get better leverage). (3 marks)

3 Submission

You need to submit one report and one Matlab script (and any necessary functions) to run your code per assignment group of 3 students. All files are to be submitted in a single ZIP file.

The report should be submitted as a PDF of **no more than 20 pages** (everything included) with **12pt font size**.

Submit them on Canvas LMS submission page as ONE .zip file which includes the one pdf file of the report and the matlab files).
Please name your files as follows:

- the .zip file should be "Assignment1_AG[#]";
- the report should be "Assignment1_Report_AG[#]";
- the main MATLAB file should be "Assignment1_Matlab_AG[#]"

NOTE: put your Assignment Group (AG) number in "[#]", eg. AG07.

Submission checklist:

- ☐ Report is no more than 20 pages
- ☐ Report has 12pt font size
- ☐ Report saved as PDF
- ☐ File names are in the right format
- ☐ Files are compressed into ONE .zip file