NATIONAL UNIVERSITY OF SINGAPORE

ME5402/EE5106 Advanced Robotics

EE5064 Dynamics and Control of Robot Manipulators

CA for Part 2 (35%)

Project #1

Instructions

1. This project is a group work aiming to build your communication and teamwork skills, and at the same time to demonstrate individual capability and initiatives. Project 1 is designed for a team of two members: **A and B**.

2. All tasks are compulsory for each group. Missing task will be penalized by marks deduction for each member or all members in the group.

3. Each group has a friendly discussion to splits the workload and an even workload distribution is suggested to ensure each member has equal chance to perform and be awarded fairly.

4. Every member is required to sign the **Honor Pledge** that is to be attached to the report. Work contribution for each member must be stated in the report clearly.

5. Identical reports from different groups are treated as cheating case. Both groups will be penalized, or subject to disciplinary actions.

6. Submission guideline:
   - Submit all your files/documents/source codes into one ZIP file to Project 1 submission under Part II Lecture by Sam Ge under. Name your grouping file name as the registration number of the first student per group, example: If your registration number is HT093376M then the file name should be Group-HT093376M.zip
   - Write all group members' names and matric numbers on the cover page.
   - Only submit one combined PDF format report for each group.
   - Your report should include proper citations for all sources.
   - Recommended format for your report: 1.5-line spacing, 12- point' Times New Roman' font,1-inch margins.
   - The submission deadline is **22/04/2022**. Late submission is not accepted.

7. If you have any questions, feel free to contact your
   GA: Yang Jiaxuan, e0671467@u.nus.edu,
   or TAs: Jin Rui, e0838680@u.nus.edu,Wang Mianhao, e0914487@u.nus.edu, Zhao Jiadong, e0673783@u.nus.edu.

Background

Nowadays, robots aided with artificial intelligence have played an increasingly important role and have been developed for an ever-increasing application from industrial automation and factory floor to households and hospitals and among others.

Different companies have been funded, and the related robots have been designed to meet the practical requirement. Among these robots, ACUR-C, a table cleaning robot is a typical intelligent robot. Such a robot processes 4 degrees of freedom (DOFs) and works in a 3-D space. A table cleaning robot contains 4 degrees of freedom, including 1 degree of freedom for up and down movement and 3 degrees of freedom for arm plane movement.

For you to achieve the sense of achievement and become competent in your job hunting in robotics, automation and computational intelligence areas, you are to apply what you have learnt in the class such as kinematics, dynamics, control, and simulation for the robots table clean robots.

With the basic understanding, you are confident for new challenges in the future such as neural network control, force control and among others as the work required.

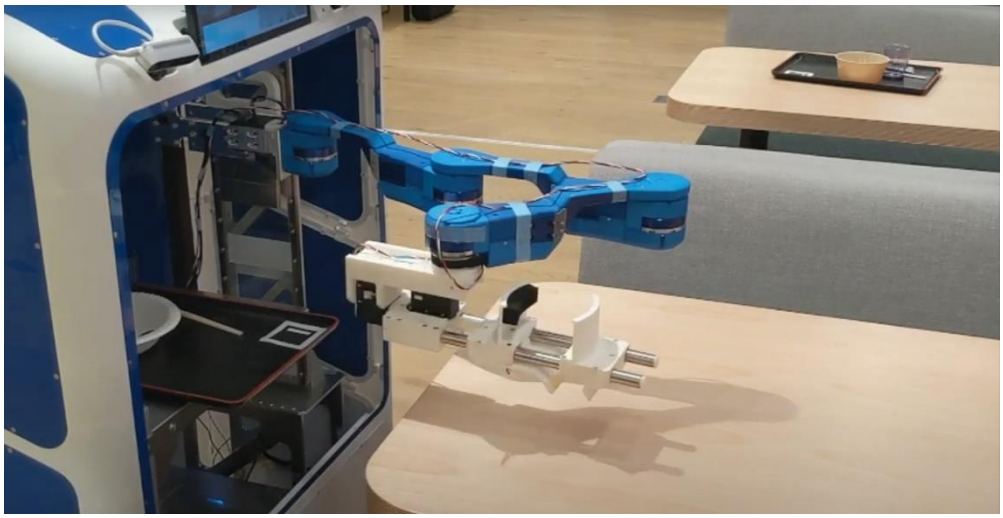

Figure 1: The table cleaning robot

Scenario

In this project, we consider the modelling and control of the ACUR-C table cleaning robot, as shown in Figure 1. The structure and geometry of the robot are presented in Figure 2. The table cleaning robot could pick up and handle a variety of tableware with AI, as well as wipe the table.

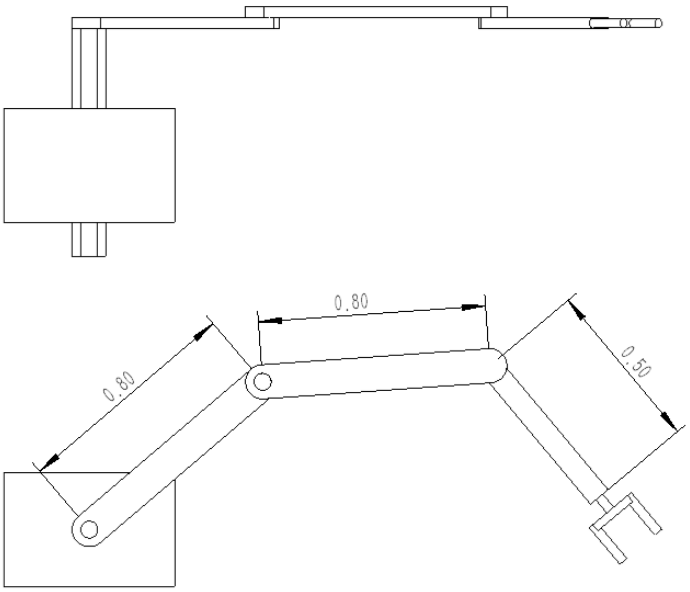

Figure 2: Structure and geometry of the robot (m)

Table of Possible Parameters of Interest

Notation	Definition	Value	Unit
θ_1	Joint angle of link 1	/	rad
θ_2	Joint angle of link 2	/	rad
θ_3	Joint angle of link 3	/	rad
m_1	Mass of link 1	1.2	kg
m_2	Mass of link 2	1.0	kg
m_3	Mass of link 3	0.6	kg
l_1	Length of link 1	0.8	m
l_2	Length of link 2	0.8	m
l_3	Length of link 3	0.5	m
I_1	Moment of inertia of link 1 at the mass center about the z axis	2.56×10^{-1}	kg • m^2
I_2	Moment of inertia of link 2 at the mass center about the z axis	2.13×10^{-1}	kg • m^2

I_3	Moment of inertia of link 3 at the mass center about the z axis	5×10^{-2}	kg • m^2

For any other parameters, you can take any values by making appropriate assumptions with good engineering understanding in international system of units, such as mass in kilogram, length in meter, time in second. Assume that the mass of each link is lumped at centre of the link.

Task 1: Introduction and Literature Review

Write a proper introduction for importance of the intelligent robot, the need for such a robot, and innovation for a solution provided by doing proper literature search for references, and web resources.

Task 2: Kinematics and Computing

i. Determine the D-H table and the Jacobian matrix of the cleaning robot (See Figure 2). Make reasonable assumptions on necessary parameters.

ii. Compute the forward and inverse kinematics of the cleaning robot in Matlab or Python.

Task 3: Dynamics and Computing

i. Determine the N-E and L-E equations of the robot arm.

ii. Design a time-varying torque as your preference. Using the Simple Integration Method you learned, compute the position, velocity and acceleration of each revolute joint Matlab or Python.

Task 4: Control Design and Simulation

i. Design a PID control for the cleaning robot to archive simple tasks, such as trajectory tracking.

ii. Do a simulation to visualize your PID control result. Discuss how the parameters influence the performance. Use any software or program languages of your preference, such as MATLAB, Python, etc.

Task 5: Conclusions and Further Studies

i. Draw conclusions from all your tasks above. Summarize any difficulties you met and how you solved them.

ii. In practical scenarios, application the cleaning robot may need to combine some other technologies. State 2 technologies that can be applied in cleaning robot application.

Important Notes:

More detail information for submission:

i. Group **source codes** must be proper documented. Write a **requirement.txt** to state an exact environment that can allow us to directly run your code. Please write a **README.md** file that explains what your codes are doing, what the main files are.

ii. Your **group report**, as a single pdf file. Put your names and matric numbers on the cover page. Clearly state every members' contribution and effort to the project in your report.

iii. Include other necessary files, such as a video file, showing the result of your simulation, etc.

Suggested Work Distributions

Assume group members are A and B. The suggested work contribution is listed in the table below. Tasks for **All** are for team discussion, brainstorming and writing, while tasks for individual member **A** or **B** is for individual lead-work and should be completely by the lead-member, though the lead-individual can discuss with the team member.

Group with 2 Members A and B

Tasks	Tasks Weightage	Suggested work distribution among members
Task 1	15%	All
Task 2	40%	A
Task 3	40%	B
Task 4	30%	All
Task 5	15%	All

Assessment for individual is based on your contribution weightage, work quality, accuracy, and contributions.