NATIONAL UNIVERSITY OF SINGAPORE

ME5402/EE5106 Advanced Robotics

EE5064 Dynamics and Control of Robot Manipulators

CA for Part 2 (35%)

Project #3

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 3 is designed for a team of three members: **A, B and C**.

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 3 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.

Objective

Recently, robots aided with artificial intelligence have attracted considerable attention in numerous scientific and engineering areas. Different types of robots have been designed and applied in industrial automation for painting, welding, assembly, ironing, and palletizing. Among these robots, the autonomous robot is the typical one. Because of its significant characteristic, the autonomous robot has been widely investigated and utilized to conduct cyclic and boring work.

In general, the study of robots can be divided into two parts: robot kinematics and robot dynamics. The former, which includes the forward kinematics and inverse kinematics, deals with the relationship between the joint variable space and the end-effector position and orientation. The latter, which is closely related to robot controller design, deals with the relationship between the robot motion and the forces/torques.

In this project, you are open to propose a robot application scenario. Your robot should contain a manipulator (arm) with 2 degree-of-freedom. The whole degree-of-freedom of your robot along with the manipulator should be around 3 so that you can finish the project with in one month.

Some Robot Cases for Your Consideration

1. Transportation robot in hospital ward where a robot dispatched medicine from nurse counter to bedded patient.
2. Parcel-sorting robot, which can support parcel sortation and bins transportation.
3. Forklift AGV (Automated Guided Vehicle) that could achieve horizontal movement and vertical lifting.
4. Legged robot, such as Spot made by Boston Dynamics, ANYmal made by ETH Zurich, etc.
5. …

For system parameters of interest, 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. You can build your table of Parameters of interest in Table I.

Table I of Possible Parameters of Interest

Length of Link i
Mass of Link i
Moment of Inertia of Link i

Task 1: Introduction and Literature Review

For the robot that you are designing for the application of your choice, write a proper introduction for importance of your work, the need for such a robot, and innovation for a solution provided by doing proper literature search for references, and web resources.

Task 2: Robot Design and Applications

Clearly describe your proposed robot and its application scenarios. Clearly state necessary parameters of your robot in international system of units, such as mass in kilogram, length in meter, etc.

Task 3: Kinematics and Computing

i. Determine the D-H table and the Jacobian matrix of your robot.
ii. Compute the forward and inverse kinematics of your robot in Matlab or Python.

Task 4: 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, or C, etc.

Task 5: Control Design and Simulation – PID control

i. Design a PID control for your robot to achieve simple tasks, such as trajectory tracking.
ii. Do a simulation to visualize your PID control result. Discuss how the parameters influence the performance, Matlab or Python or C, etc.

Task 6: Control Design and Simulation – other type of controller

i. Design another controller, such as Computed Torque Method, Adaptive Control or Adaptive NN Control that you are confident for trajectory tracking.
ii. Do a simulation to visualize your control result. Discuss how the parameters influence the performance.
iii. Compare the result with PID control (in Task 5) and discuss why PID control has a better/worse performance.

Task 7: Conclusions and Future Work

i. Draw conclusions from all your tasks above and state how to improve your work in the future. Summarize any difficulties you met and how you solved them.
ii. In practical scenarios, robot application may need to combine some other technologies. State 2 technologies that can be applied on your robot.

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. Also, 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, B and C. 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, B** or **C** is for individual led-work and should be completely by the lead-member, though the lead-individual can discuss with the team member.

Group with 3 members

Tasks	Tasks Weightage	Suggested work distribution among members
Task 1	10%	All
Task 2	20%	All
Task 3	40%	A
Task 4	40%	B
Task 5	40%	C
Task 6	20%	All
Task 7	10%	All

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