NATIONAL UNIVERSITY OF SINGAPORE

ME5402/EE5106 Advanced Robotics

EE5064 Dynamics and Control of Robot Manipulators

CA for Part 2 (35%)

Project #2

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 2 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

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. For example, Kiwibot, a four-wheel autonomous robot, can pick up orders and deliver them to destinations automatically as shown in Figure 1.

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 a mobile robotic manipulator as shown in Figures 2 and 3.

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 autonomous delivery robot Kiwibot, California, US

Scenario

In this project, we consider modelling and control of a four-wheel autonomous robot based on the Kiwibot. The geometry of the four-wheel robot is presented in Figure 2. This four-wheel model is to execute moving and turning. Assume that two front wheels are the driving wheels and the others are the driven wheel. On top of it, we add a 2-link robot arm on the center top of the robot. Both these two joints are revolute joint. When the robot reaches the target location, the robot arm will execute object grasping mission. Under this circumstance, the robot could rotate in place in order to reach the object and we can regard the rotating robot as a revolute joint. Link 1 is fixed to the robot. A simplified model is shown in Figure 3.

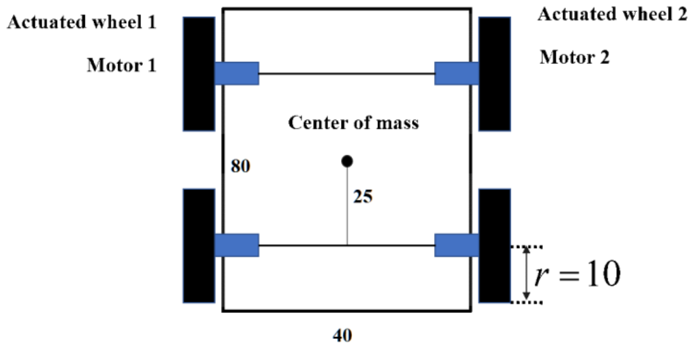

Figure 2: The geometry of a four-wheel robot (cm)

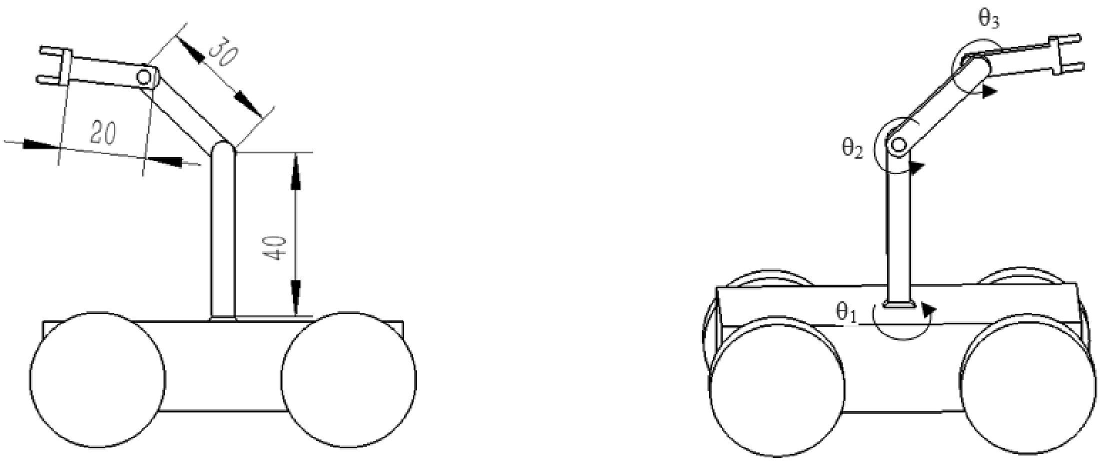

Figure 3: Structure and geometry of robot arm (cm)

Table of Possible Parameters of Interest

Notation	Definition	Value	Unit
ω_1	Rotation angle of actuated wheel 1	/	rad
ω_2	Rotation angle of actuated wheel2	/	rad
r	Radius of the wheel	0.1	m
l_a	Width of the robot	0.4	m
l_b	Length of the robot	0.8	m
l_c	Distance from the center point of the platform to the wheel rotary shaft	0.25	m
m_c	Mass of the robot (Including link 1)	4	kg
m_w	Mass of the wheel	1	kg
I_Z	The moment of inertia of the robot(including link 1)	6×10^{-1}	$kg \cdot m^2$

I_w	The moment of inertia of the wheel	5×10^{-3}	$kg \cdot m^2$
θ_1	Joint angle of the robot	/	rad
θ_2	Joint angle of the link 2	/	rad
θ_3	Joint angle of the link 3	/	rad
m_1	Mass of the link 2	1	kg
m_2	Mass of the link 2	1	kg
m_3	Mass of the link 3	0.6	kg
I_2	The moment of inertia of link 2	3×10^{-2}	$kg \cdot m^2$
I_3	The moment of inertia of link 3	8×10^{-3}	$kg \cdot m^2$
l_1	Length of link 1	0.4	m
l_2	Length of link 2	0.3	m
l_3	Length of link 3	0.2	m

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: 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 robot as shown in Figure 3. Taking the autonomous car as a revolute joint, we actually have a 3-joint robot arm.
ii. Compute the forward and inverse kinematics of the robot arm as show in Figure 3 Matlab or Python.

Task 3: Dynamics and Computing

i. Determine the N-E and L-E equations of the robot.
ii. Design a time-varying torque as your preference. Using the Simple Integration Method you learned in the lectures, compute the position, velocity and acceleration of each joint Matlab or Python.

Task 4: Control Design and Simulation

i. Design a PID control for the autonomous 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 of autonomous robots may need to combine some other technologies. State 2 technologies that can be applied in autonomous 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

Tasks	Task 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.