Robotic Manipulation – ELEC60030

Coursework 2024 – Robot Arm Modelling and Control

Evaluation

The coursework consists of four tasks which will be evaluated via the following three methods:

1. Report – 75 marks (37.5%)

The report has a maximum length of 7 pages + appendix.

The appendix should contain your inverse kinematics calculations and screenshots of any CAD models you have created.

2. Video Demo – 65 marks (32.5%)

The video demo should show your robot completing tasks listed in this document. Each task has videos associated with it. The videos will be based on pre-defined task parameters (such as cube location and orientation for Task 2).

You must submit a single video file demonstrating your robot completing the various tasks. You should film this with your smartphone using the provided tripod and adapter. Choose a good camera angle that shows relevant aspects of the robot and object. You should edit out irrelevant footage and combine the relevant footage to appear in sequence. Use text to display your team name at the start of the video.

3. Live Demo – 60 marks (30%)

All groups will demo their work on 'demo day' in week 10. For demo day you will have to show your robot completing tasks 2, 3 and 4. New parameters for Tasks 2 and 3 (cube locations and orientations) will be provided at **8am** on demo day. We use new parameters for demo day to make sure that your solutions are generalisable.

There will be a sign-up sheet where you will select a time to demonstrate each task. There will be 'pit stops' where you can attach your 3D printed robot modifications and test your code. Demos will be evaluated by the module leader and GTAs.

Housekeeping

All work will be carried out on the Robotis Manipulator-X robot.

Programming and simulations should be carried out only in Matlab.

You will need to hand in your code, which should run in a self-contained fashion without reliance on external libraries or code.

You cannot use the Matlab Robotics Toolbox. This makes things too easy and negates the learning outcomes.

You cannot use any code or libraries from Matlab File Exchange. That place is a wild west of poor resources.

Please leave the robots as you expect to find them. If you change the baud rate, PID controllers or anything else, change it back when you are done.

Tasks

The coursework consists of four tasks, which are as follows.

Note that Task 1 is compulsory, but you do not need to do all of the other tasks.

Task 1 - Model the robot (Report)

This task can be done at home without the robot present. It is important to do this task well, as it will generate the controller you need to

1.a.	Assign co-ordinate frames to the robot and create a DH notation table. Illustrate and explain your frame choices in the report. Note that there are multiple ways to assign frames to the robot. Some will lead to more complicated equations than others. The dimensions of the robot are in the appendix.	**10**
1.b.	Create a graphical simulation of the robot, based on your DH Table. This only needs to consist of line() objects in Matlab. Increasing the thickness of the line can make the simulation easier to see, particularly after video compression. Plot the co-ordinate frames (as I do in class, with appropriate colours) for additional marks. Run forward kinematics by incrementing joint angles and plotting the robot. This is a good way to ensure that your DH parameters make sense. Make a video demonstrating your forward kinematics simulation. You can use a screen recorder or the video functions built into Matlab.	**9**
1.c.	Determine a solution to the inverse kinematics for a frame located between the jaws of the gripper. Numerical solutions will receive less marks than analytic solutions. For analytic solutions, It helps to consider the robot as subsystems. Perhaps try to only solve IK to the elbow first. It also helps to only consider the position components of the gripper.	**12**
1.d.	Re-run your simulation with the inverse kinematics. Get your robot to trace a square of 10 x 10 cm in each cartesian plane. Be sure to draw the square (use line objects of different colours). Make a video of this (marked separately).	**9**
	Total marks for Task 1	**40**

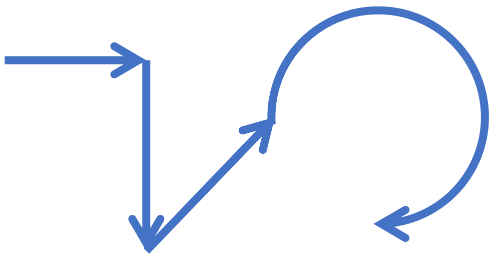
Task 2 – Pick and Place (Video Demo)

For this task you will use the robot to pick up and move 25mm width wooden cubes located on the baseplate of the robot. The cubes will always be on the grid in a shallow, 3D printed holders. The cubes will always radially align with the robot base. The robot must start in the 'home' position.

2.a.	Pick up the cubes from the three starting locations and transfer them to three finishing location. You can choose which cube goes to which finishing location. The starting and finishing locations are in the appendix.	**12**
2.b.	The cubes will now be in the starting locations but with the red face positioned either to the front (away from the robot), back (towards the robot) or down (towards the ground). Pick up the cubes and rotate them so that the red face is at the top. Place them back in the same location. The orientations are in the appendix.	**12**
2.c.	The cubes will be in the starting locations but with the red faces positioned as in 2.b. You must stack all the cubes in any finishing location, with all red faces facing away from the robot. You will get half the marks for stacking and half the marks for rotating. So if you haven't done 2.b. you can still attempt 2.c and get some marks.	**16**
	Total marks for Task 2	**40**

Task 3 – Trajectory Following (Drawing) (Video Demo)

This task involves picking up a pen and drawing a pattern on a sheet of acrylic attached to the baseplate. The robot must start in the ‘home’ position. The pen will be a whiteboard marker from EEE stores. Each group will be given a pen.

3.a.	Using the standard OpenManipulator robot gripper to hold the pen leads to an unstable grasp, with the pen pivoting for any drawing motions in a radial direction relative to the robot base. By ‘radial’ I mean any imaginary line starting at the robot base and moving outwards. Some of these have been drawn on the baseplate. Design and 3D print a method of securely holding the pen with the robot. This can either involve modifying the fingers, modifying the pen or both. The robot must be able to both grasp and let go of the pen.	**20**
3.b.	Draw the pattern. The robot must begin the task not holding the pen. Pick up the pen and draw the pattern listed in the appendix. The pattern will involve 3 straight lines (horizontal, vertical and diagonal) and 1 partial circle (an 270deg arc with constant radius). This is not the pattern, just an example. You will get 3 marks for picking up the pen, 3 marks for each straight line completed and 6 marks for the partial circle. 	**20**
	Total marks for Task 2	**40**

Task 4 – Own Task (Video Demo)

Using what you have learned during the course, come up with a robot manipulation task and execute it with your robot.

Some example tasks include

1. Making coffee
2. Feeding a disabled person with limited arm control
3. Picking apples

You can use physical props to make your task more realistic, and it is fine to scale these to the size of the robot. Props can be purchased (must be <£10) or 3D printed (look for files on Thingiverse.com before designing them yourself). Consider using the holes in the baseplate to help position your props.

Note that tasks cannot involve actual liquids. You can either pretend that your coffee container has liquid in it, or you can use a granular material with grains larger than 4mm. Something like rice or dry chickpeas would work. You must clean up any spilled grains.

4.a.	Originality – selection of an interesting / novel task. The task needs to be motivated by some idea / application. This can be as simple and fun as 'giving me a drink when I'm working late' or more industry focused such as 'packing groceries at a warehouse'. You will have a few minutes at the start of your demo for an 'elevator pitch' to describe what you are attempting to do.	**10**
4.b.	Challenge – don't choose a task that is too easy to complete. Select something that requires demonstration of the knowledge you have learned during the course. The more challenging the task, the higher the grade.	**5**
4.c.	Solution – Demonstrate that you have solved the problem through robot programming and part design.	**25**
	Total marks for Task 3	**40**

Report

Task 1 – Modelling	– 40 marks	
Task 2 – Pick and Place	– 10 marks	
Task 3 – Drawing	– 10 marks	
Task 4 – Own Task	– 15 marks	(include motivation)

Total - 75 marks

Video Demo

Task 1	– 8 marks
Task 2	– 16 marks
Task 3	– 16 marks
Task 4	– 20 marks
Video Quality	– 5 marks

Total - 65 marks

Live Demo

Task 2 – Pick and Place	– 20 marks
Task 3 – Drawing	– 20 marks
Task 4 – Own Task	– 20 marks

Total - 60 Marks

For each live demo we evaluate:

Accuracy	– 7 marks	(completing the given task)
Smoothness / Method	– 6 marks	(clear trajectories, smooth motion)
Time Taken	– 7 marks	(Task 2 & 3)
Novelty and Style	– 7 marks	(Task 4)

Total – 20 Marks

TOTAL MARKS = 200

70% = 140