ELEC-C1110 Basics of Automation and Systems Engineering

Assignment 5
Spring 2023

Introduction

The fifth exercise examines the kinematics of the 2 DOF - robotic arm and the position adjustment of the gripper. The position adjustment setpoint changes in a staggered manner every 50 seconds so that the desired gripper cartesian co-ordinates (x and y) are taken from the vectors below:

$$x = [-0.75 \quad -0.75 \quad 1.50 \quad -0.75 \quad -0.75 \quad 1.50]$$
$$y = [0.75\sqrt{3} \quad -0.75\sqrt{3} \quad 0.00 \quad 0.25\sqrt{3} \quad -0.25\sqrt{3} \quad 0.00]$$

For a desired gripper cartesian position, the corresponding joint angles (shoulder and elbow) are determined using inverse kinematics. The gripper is then directed to the desired cartesian position by setting the joint angles to the appropriate values. The Joint position controllers use PID for controlling the joint torques. Each of the joints (shoulder and elbow) has its own PID controller. The performance of the controller is evaluated by comparing the plots of desired joint angles and the actual joint angles (executed by the robot). Finally, the actual joint angles are used to determine the cartesian co-ordinates using forward kinematics. Compare the desired and actual cartesian trajectories of the robot gripper. The controller, robot dynamics and the simulation are implemented in python script. For the given python template, you need to implement forward and inverse kinematics. In addition, you need to tune the PID controller parameters to execute the desired trajectory in a smooth fashion.

For the report, use the 5-report template found in MyCourses. Fill in your student number, name and group number in the space provided. Write down the answers to the assignments in the relevant sections. Return the completed report in pdf format. In addition to the report, remember to return the Python code that you have used.

Tasks

Task 1: Using chained transformations, derive the equations of the robot's forward kinematics. So, introduce the transformation matrices and use them to form equations for the xy coordinates of the gripper as a function of the angles of the shoulder and elbow joints (show enough intermediate stages of multiplication).

Task 2: Derive the equations of inverse kinematics of the robot. You can look up the lecture slides for reference. Also, explain the steps involved.

Task 3: Complete the missing code in Python template. Implement forward and inverse kinematics functions. Also, fine-tune the PID parameters for both (shoulder and elbow joint) PID controllers. More detailed instructions are provided in the python notebook. Hints are provided too.

Task 4: In the report, write down the PID parameters that you have used. Explain about your experiments and your criteria for choosing these parameters. Attach the comparison plots of desired and actual trajectories generated using python script. Does your desired trajectory exactly match the desired trajectory? If not, what differences do you observe and what might have caused them?

Task 5: Explain why PID output signals are clipped (refer *step* function in *PIDController* class)? Think about what could be the problems of applying an unclipped signal to a real-world robot joint motor.

Task 6: Mention at least two problems related to the fact that the position of the gripper is adjusted simply by directing the angles of the shoulder and elbow joints to the values calculated using inverse kinematics. Briefly explain how these problems or specialties of position control could be corrected.