EC4.401 Robotics: Dynamics and Control
Assignment 2
Robotics Research Center
International Institute of Information Technology Hyderabad

Total Marks	: (100)
Due Date	: 20-10-2024
Late Submission	: Each day after the due date will receive a penalty of 1 mark - deduced from the total marks obtained.

Instructions:
Students should
1) write the code individually.
2) submit the script, images, and graphs with the program outputs in their respective folder provided in the zip.
3)create a common PDF report for the handwritten questions.
4) submit the assignment as zip named as roll_number.zip

Answer all the questions:

1. Using the Euler angles ZYX convention, parameterize the rotation matrix (R) (15 marks)

   1.1 Find R: Assume all the consecutive rotations occur with respect to {s} frame. Write a function that takes Euler angles (θ_1,θ_2,θ_3) as inputs and outputs R matrix (3)

   1.2 Solve for the Euler angles: Write a function that takes R as input and outputs (θ_1,θ_2, θ_3) (8)

   1.3 Test the algorithm considering the nonsingular and singular configurations (1)

   1.4 Graphically show {b} and {s} frames for the given (θ_1,θ_2,θ_3) (3)

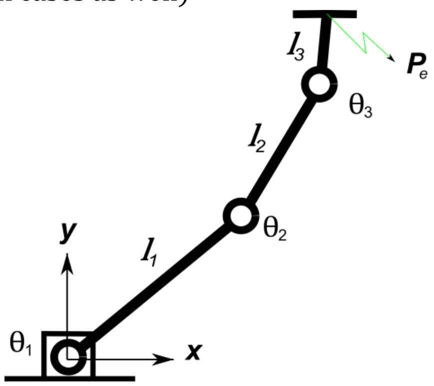
2. Refer to the 3R planar manipulator shown below. (35 marks)

   2.1 Find the end-effector tool position (5)

   2.2 Graphically demonstrate the forward kinematics and show the dexterous workspace. For every change in joint angles, show the corresponding configuration graphically on 4 positions. (10)

   2.3 Using geometric inverse kinematics, write a function that takes the end effector position [x,y] as an input and outputs the joint angles. (The function should handle elbow-up and elbow-down cases.) (10)

2.4 Compare the output joint angles from IK function with the input angles you used in FK and graphically demonstrate both the original configuration and the configuration(s) obtained from inverse kinematics. (4 Cases) (Include elbow-up and elbow-down cases as well) (10)



3. We have already discussed the relation between the axis-angle and the rotation matrix in the class. (15 marks)

$$\boldsymbol{R} = (\mathbf{I} + \sin\theta\hat{\mathbf{n}} + (1 - \cos\theta)\hat{\mathbf{n}}^{2})$$

3.1 In continuation with that, find $\boldsymbol{n} = [n_1\, n_2\, n_3]^T$ and θ for a given generalized rotation matrix $\boldsymbol{R} = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}$. (5)

3.2 Write a program that takes $\boldsymbol{n}$, θ as inputs and returns the corresponding rotation matrix, and vice versa. Show the output graphically. (5)

3.3 Given a rotation matrix R, convert it to a quaternion representation q = [w, x, y, z]? Implement this conversion in your program and demonstrate its output graphically. (5)

4. DH representation for a UR5 manipulator (35 marks)

4.1 Find the DH parameters for the robot shown below*. (10)

4.2 Write a function that inputs DH parameters and returns the transformation matrix. Using this function, derive the end-effector pose with respect to the base frame {0}. (15)

4.3 Validate with the home configuration. (3)

4.4 Shown the robot configuration graphically. (7)