EC4.401 Robotics: Dynamics and Control
Assignment 3
Robotics Research Centre
International Institute of Information Technology Hyderabad

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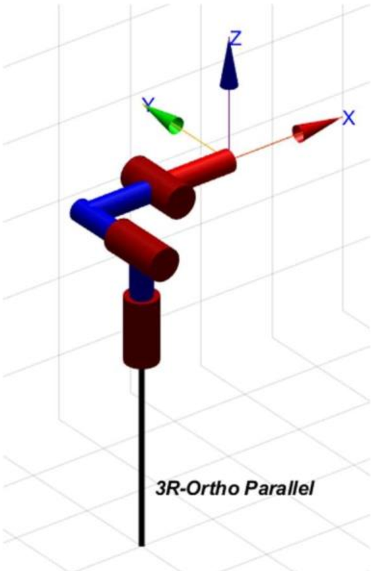
| Total Marks | : 60 Marks |
| Due Date | : 14-11-2024, 11:55 PM |

Instructions:
Students should 1) Write the code individually.
2) Submit the script, video, and document with the program outputs. 3) Use of both MATLAB and Python is allowed, but consistency should be maintained for all parts of the assignment. 4) Assume unit link length wherever necessary.

Note:
1) It is acceptable to use symbolic toolboxes for derivations.
2) For simulation, the Robotics toolboxes by Peter Corke are highly recommended; resources will be uploaded, and tutorial will be given to explain the use. 3) All the questions are to be solved for the manipulator given in Q1.

Answer all the questions:

1. Forward Kinematics: (5+5+5+5 marks)
   1.1 Write the DH table for the given 3R-Spatial manipulator.
   1.2 Write a DH function that takes DH parameters as input arguments and outputs all the transformation matrices. i.e. Matrices for every joint with respect to the previous joint




   1.3 Write an FK function that takes joint angles as input arguments and outputs the endeffector pose; Make use of the DH function, and check if the answer from 1.3 matches with your answer obtained from code.
   1.4 Simulate and show the manipulator's home configuration using the recommended MATLAB/Python Robotics toolbox.

2. Inverse Kinematics: (5+5+5 marks)
   2.1 Theory: Derive the Inverse Kinematic solutions for the manipulator.
   2.2 Write an IK function that takes the end-effector pose as an input argument and outputs the joint angles.
   2.3 For any point inside the workspace, how many solutions are possible for that End Effector position? Show all the solutions graphically for the given end-effector pose.

3. Velocity Kinematics: (5 + 5 marks)
   3.1 Use the recursive algorithm and compute linear and angular velocities for all the frames and show the full Jacobian for the manipulator.
   3.2 Find Singularity conditions and graphically show the singular configurations.

4. 2R Manipulator Dynamics: (5 + 5 + 5 marks)

   Using MATLAB, write a script to simulate the dynamics of a 2R planar manipulator. The manipulator has link masses $m_1$ *and* $m_2$, link lengths $l_1(t)$ *and* $l_2(t)$ and moments of inertia $I_1(t)$ *and* $I_2(t)$.

   4.1 Define the manipulator's equations of motion using the Lagrangian method to obtain the mass matrix $M(\theta)$, Coriolis/centrifugal matrix $C(\theta, \dot{\theta})$, and gravitational torque vector $G(\theta)$.
   4.2 Implement these equations in MATLAB, then use **ode45** to numerically solve for the joint angles $\theta_1(t), \theta_2(t)$, over time given initial angles and velocities.
   4.3 Visualize the results by plotting the joint angles $\theta_1(t)$ and $\theta_2(t)$ over time and animate the manipulator's motion.