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MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

SEVENTH SEMESTER B.TECH. (INSTRUMENTATION AND CONTROL ENGG.)

END SEMESTER DEGREE EXAMINATION, MARCH - 2021

ROBOTICS SYSTEMS AND CONTROL [ICE 4030]

19-03-2021

TIME: 3 HOURS MAX. MARKS: 50

Instructions to candidates :*Answer ALL questions and missing data may be suitably assumed.*

1A. Find the final global position (${}^{G}r_{P}$) of a body point at ${}^{B}r_{P} = [10, 10, -10]^T$ after:
(a) A rotation of 60 deg about the W-axis,
(b) A rotation of -30 deg about the X-axis,
(c) A translation of $[-2, 3, 1]^T$ wrt the local frame of reference UVW, and finally,
(d) A rotation of 90 deg about Z-axis.
Assume that the origins of both frames of references coincided initially at $[0\ 0\ 0]^T$.

1B. The DH parameters for a 3-DOF manipulator is given in Table Q1B.

Table Q1B

a	**d**	**θ**	**α**
1	1	θ_1	0
3	2	θ_2	90^0
1	0	θ_3	0

Obtain the end-effector position and orientation matrices when the joint space (q) is given as:

$$[q] = [\theta_1\ \theta_2\ \theta_3]^T = [30^0, -30^0, 60^0].$$

1C. Determine the inverse of the following homogeneous transformation matrix.

$$\begin{bmatrix} 0.7 & 0 & 0.5 & 4 \\ 0.5 & 0 & -0.7 & 5 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(3+5+2)

2A. A 3-DOF RRP configured manipulator has its position and orientation of end-points given (in Cartesian space) as follows:

$$\begin{bmatrix} 0.354 & 0.866 & 0.354 & 0.106 \\ -0.612 & 0.5 & -0.612 & -0.184 \\ 0.707 & 0 & 0.707 & 0.212 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Determine the feasible values of the joint variables, assuming the joint limits as follows:

$$-100 < \theta_1 < 100 \text{ (in deg.)}$$
$$-30 < \theta_2 < 70 \text{ (in deg.)}$$
$$0.05 < d_3 < 0.5 \text{ (in m)}$$

2B. The end-effector of 2-link R||R manipulator (with each link 1m long) is required to move from its initial position (0.9, 1.6, 0) to the final location (-1.6, 0.5, 0) in 5 seconds, such that the end effector between these two points will move in a straight line. Design a polynomial of degree 3(joint space) trajectory planning for the second joint at both points (with at the least one via-point between them). Assume any missing data judicially.

(4+6)

3A. The DH parameters for a 1-DOF manipulator is given in Table Q3A. Assume the link to be a slender/thin cylinder and that the link-mass 'm' (≈ 300gm) is acting at the centroid of the link.

Table Q 3A

a	d	θ	α
10cm	0	θ_1	0

Using Euler-Lagrangean algorithm, determine the dynamic model of the given manipulator.

3B. A linear trajectory (with parabolic blends) is used for one of the revoluting joints of an n-DOF manipulator. Assuming a constant acceleration of 30 deg/s^2 during the blending regions, determine the parameters of the trajectory if the joint has to move from 113deg to 210deg in 7s. Let the joint is at rest for both initial and final positions.

(5+5)

4A. The DH parameters for a 3-DOF manipulator is given in Table Q4A.

Table Q 4A

a	d	θ	α
0	0	θ_1	-90^0
0	0	θ_2	90^0
0	d_3	0	0

Obtain the joint space solutions in terms of the position coordinates of end-effector.

4B. The home configuration of a given manipulator correspond to the given DH Table Q4B.

Table Q 4B

a	d	θ	α
0.4	0	θ_1	90^0
0.4	0	θ_2	90^0
0	d_3	0	90^0
0	0	θ_4	0

Determine the following when the manipulator is in a configuration, $q = [30^0 \;\; 45^0 \;\; -0.3\text{m} \;\; 60^0]^T$.

(i) Angular velocities of each joint

(ii) Linear Velocities of each joint.

(iii) Jacobian Matrix (J).

(4+6)

5A. The hand frame of a RRRRRR robot and the corresponding Jacobian matrix are given as follows.

$$T = \begin{bmatrix} 0 & 1 & 0 & 10 \\ 1 & 0 & 0 & 5 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad J = \begin{bmatrix} 8 & 0 & 0 & 0 & 0 & 0 \\ -3 & 0 & 1 & 0 & 0 & 0 \\ 0 & 10 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

For differential changes of joints given by $[0\ 0.1\ -0.1\ 0.2\ 0.2\ 0]^T$ (in rad.), compute the change in hand frame and its new spatial configurations.

5B. For Q5A., if the third and fifth joints of the robot exhibit kinematic singularity, determine the inverse of the modified Jacobian matrix.

5C. Using the DH Table Q4B., determine the joint configurations of the manipulator that may lead to kinematic singularity(ies).

(3+5+2)

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