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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 EXAMINATIONS, DECEMBER - 2019

SUBJECT: ROBOTIC SYSTEMS AND CONTROL [ICE 4030]

TIME: 3 HOURS MAX. MARKS: 50

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

1A. A rigid body is translated by 2 units along the X-Axis, then rotated about the –Z axis by 30^0 and finally translated by a distance of 4 units along the Y axis. Determine the homogeneous transformation matrix.

1B. Calculate the degrees of freedom for the mechanism shown in Fig. Q1B.

1C. Given the homogenous transformation matrices ${}^aT_b$ and ${}^cT_b$, find the transformation matrix ${}^aT_c$.

$$ {}^aT_b = \begin{bmatrix} 0.867 & -0.5 & 0 & 11 \\ 0.5 & 0.867 & 0 & -1 \\ 0 & 0 & 1 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad {}^cT_b = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.867 & 0.5 & 10 \\ 0 & -0.5 & 0.867 & -20 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

1D. List the basic elements of a robot. Also, determine the orientation matrix {R} w.r.t RPY angles $q = \begin{bmatrix} 30^0 & -45^0 & 60^0 \end{bmatrix}$

(2+2+4+2)

2A. Explain why D-H representation does not give unique frame assignment for any given manipulator.

2B. Define manipulator workspace. How does reachable workspace differ from dextrous workspace?

2C. With a relevant example, differentiate between constrained and unconstrained kinematic motions.

2D. Obtain the end-effector coordinates for the manipulator shown in Figure Q2B. Given that the coordinates of the base frame {0} is $[0\ 0\ 0]^T$. Assume: L_1=10, L_2=4, L_3=2, d_1=0.5 (all units in cm)

(2+2+2+4)

3A. For Q2D, determine all possible joint configuration(s) corresponding to kinematic singularity for the manipulator.

3B. Given that the homogeneous transformation matrix (${}^0T_E$) (i.e. end-effector w.r.t. base frame) for a 3DoF manipulator is as given below. Determine the joint space $q = [\theta_1 \quad \theta_2 \quad d_3]^T$

$$ {}^0T_E = \begin{bmatrix} C_1C_2 & -S_1 & -C_1S_2 & -d_3C_1S_2 \\ S_1C_2 & C_1 & -S_1S_2 & -d_3S_1S_2 \\ S_2 & 0 & C_2 & d_3C_2 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

3C. Explain how Skew symmetric matrix (S) is related to the angular velocity of a link for an N-dof arm.

(5+3+2)

4A. Differentiate between:

(i) Path and trajectory

(ii) Joint Space Trajectory and Cartesian Space Trajectory

4B. A rotary joint moves from -15^0 to $+45^0$ in 3 seconds. Determine a fifth order polynomial for a smooth joint trajectory. Also plot the position, velocity and acceleration of the joint as a function of time (t). Assume both velocity and acceleration to be zero at t=0s and t=3s.

4C. In Cartesian straight-line path planning, *linear-trajectory-with-parabolic-blends* is more appropriate. Why?

(3+5+2)

5A. List the various types of proprioceptive and exteroceptive sensors used in robots.

5B. Draw and explain the block-diagram for a partitioned PD controller for the trajectory control of a 1-dof rotary joint.

5C. (i) Number of rows in the Jacobian matrix corresponds to _____ (taskspace dimension / dof).

(ii) State TURE or FALSE: "The inertia-matrix M(q) is symmetric and uniformly positive - definite for all $q \in \mathbb{R}^n$."

5D. For the hand-frame of a 5-dof (RRPRR) robot, the instantaneous values of its forward-kinematic transformation and Jacobian matrices are given as follows. Determine the new location of the hand-frame after the given differential motions (dq).

$$J = \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ -2 & 0 & 1 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix} \quad {}^0T_5 = \begin{bmatrix} 1 & 0 & 0.1 & 5 \\ 0 & 0 & -1 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad dq = \begin{bmatrix} 0.1^0 & -0.1^0 & 0.05cm & 0.1^0 & 0^0 \end{bmatrix}$$

(2+2+2+4)

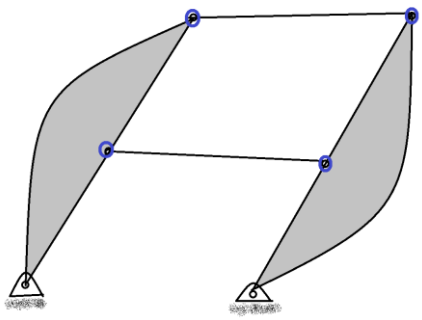

Figure Q1B

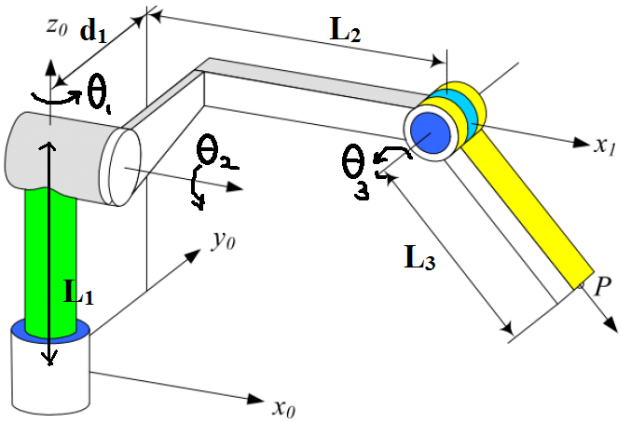

Figure Q2B

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