U.S.N.										

B.M.S. College of Engineering, Bengaluru-560019

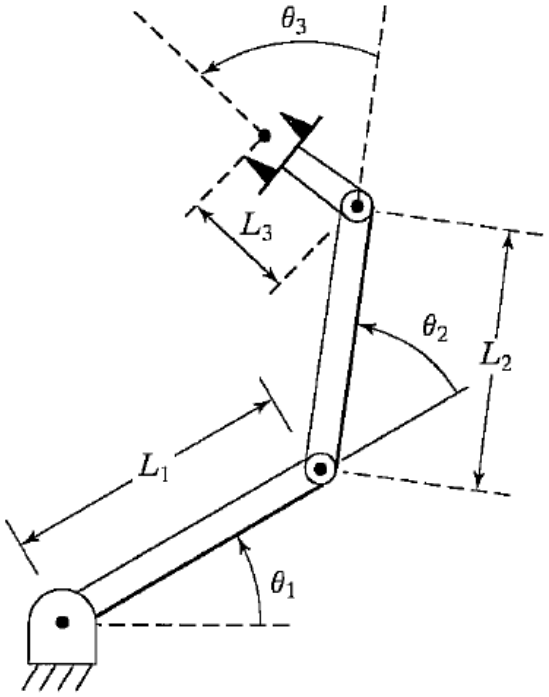
Autonomous Institute Affiliated to VTU

July 2023 Semester End Main Examinations

Programme: B.E. **Semester: VI**
Branch: Mechanical Engineering **Duration: 3 hrs.**
Course Code: 20ME6DEROB **Max Marks: 100**
Course: Fundamentals of Robotics **Date: 17.07.2023**

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.

Important Note: Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

		UNIT - I	CO	PO	Marks
1	a)	A vector ${}^{A}P$ is rotated about $\hat{X}_A$ by 90 degrees and is subsequently rotated about $\hat{Y}_A$ by 90 degrees. Give the rotation matrix that accomplishes these rotations in the given order.	*CO1*	*PO2*	**10**
	b)	List the properties of rotation matrix and show that the matrix $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{pmatrix}$ is a valid rotation matrix.	*CO1*	*PO1*	**10**
		OR			
2		For the planar 3R manipulator shown in Fig. 2, assign link frames, give the DH parameters and find the transformation matrices ${}^{0}_{1}T, {}^{1}_{2}T, {}^{2}_{3}T, {}^{3}_{Tool}T \text{ and } {}^{0}_{Tool}T$.  Fig. 2	*CO2*	*PO2*	**20**

			Hint: $${}^{i-1}_{i}T = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -s\alpha_{i-1}d_i \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1}d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$			
			UNIT - II			
3	a)		Perform the inverse kinematics for the Planar 3R manipulator using analytic approach. The position and orientation of the wrist frame (3) relative to the base frame (0) is given by the transformation matrix ${}^{0}_{3}T = \begin{pmatrix} c_{123} & -s_{123} & 0 & l_1c_1 + l_2c_{12} \\ s_{123} & c_{123} & 0 & l_1s_1 + l_2s_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$. If the desired position and orientation of the wrist frame is given by $\begin{pmatrix} c\phi & -s\phi & 0 & x \\ s\phi & c\phi & 0 & y \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$ find the joint angles.	*CO2*	*PO2*	**10**
	b)		Discuss about workspace of a robot and its types with examples.	*CO2*	*PO1*	**10**
			OR			
4	a)		For the SCARA robot the position and orientation of the last link is given by ${}^{0}_{4}T = \begin{pmatrix} c_{124} & -s_{124} & 0 & a_1c_1 + a_2c_{12} \\ s_{124} & c_{124} & 0 & a_1s_1 + a_2s_{12} \\ 0 & 0 & 1 & -d_3 \\ 0 & 0 & 0 & 1 \end{pmatrix}$. Derive the 6x6 basic Jacobian that relates the joint velocities and end effector velocities.	*CO2*	*PO1*	**10**
	b)		Discuss resolved motion rate control with a block diagram.	*CO2*	*PO1*	**10**
			UNIT - III			
5	a)		A single robot with a rotary joint is motionless at θ = -5 degrees. It is desired to move the joint in a smooth manner to θ = 80 degrees in 4 seconds. Find the coefficients of a cubic that accomplishes this motion and brings the manipulator to rest at the goal. Also sketch the position, velocity and acceleration of the joint as a function of time.	*CO3*	*PO2*	**10**
	b)		Discuss about cartesian path planning and geometric problems associated with it.	*CO3*	*PO1*	**10**
			UNIT - IV			
6	a)		Explain inverse kinematics based independent joint control scheme of a robot manipulator with a block diagram.	*CO4*	*PO1*	**10**

		b)	Explain how a single joint of a robot can be controlled with the partitioned controller along with the equations. State the assumptions involved.	*CO4*	*PO1*	**10**
			UNIT - V			
	7	a)	Explain the working principle of DC servo motor with neat sketches.	*CO4*	*PO1*	**10**
		b)	Explain the working principle of optical encoder with neat sketches.	*CO4*	*PO1*	**10**

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