BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE

Second Semester 2022-23

Mid-semester Examination (16th March 2023)

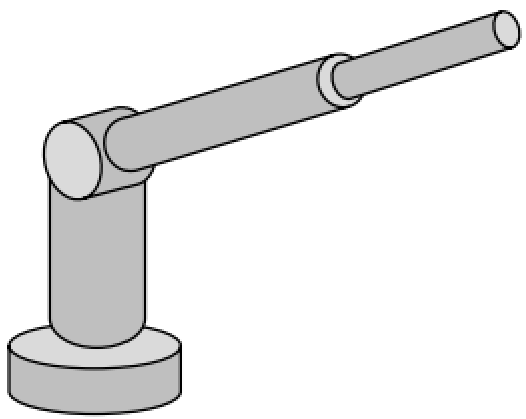
Course No. BITS F441 Robotics

Total Marks: 30 1 hour 30 Min

Q1. Consider the arm shown in the figure.

(i) Identify the links, types of the joint and workspace will it have?
(ii) Assign frames and determine link and joint parameters using DH Algorithm.
(iii) Determine the kinematic model
(iv) Determine inverse kinematic model for the given configuration.

Clearly specify valid assumptions if any. [2+4+4+2]



Q2. List down the social and economic consequences an engineer must consider the use of robots. [3]

Q3. Determine a frame {F} from {0} that is located at 4,6,8 units with its n-axis parallel to the x-axis, its o-axis at 60^0 relative to y-axis and its a-axis at 45^0 relative to z axis. [3]

Q4. For the following rotation matrix find the missing values: $\begin{bmatrix} ? & 0 & -1 \\ ? & 0 & 0 \\ ? & -1 & 0 \end{bmatrix}$ [3]

Q5. Determine the composite rotation matrix generated by a rotation of 60^0 about z_0 followed by a rotation of 30^0 about y_0 followed by rotation of 90^0 about the x_0 axis. From the resultant composite matrix obtain the axis and angle information. [6]

Q6. Find the expression for the inverse of ${}^{i-1}T_i$ matrix [3]

Formula Set

$$\mathbf{T} = \begin{bmatrix} R & D \\ O & 1 \end{bmatrix}$$

$$^{i-1}\mathbf{T}_i = \begin{bmatrix} C\theta_i & -S\theta_i C\alpha_i & S\theta_i S\alpha_i & a_i C\theta_i \\ S\theta_i & C\theta_i C\alpha_i & -C\theta_i S\alpha_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\boldsymbol{R}_k(\theta) = \begin{bmatrix} k_x^2 V\theta + C\theta & k_x k_y V\theta - k_z S\theta & k_x k_z V\theta + k_y S\theta \\ k_x k_y V\theta + k_z S\theta & k_y^2 V\theta + C\theta & k_y k_z V\theta - k_x S\theta \\ k_x k_z V\theta - k_y S\theta & k_y k_z V\theta + k_x S\theta & k_z^2 V\theta + C\theta \end{bmatrix}$$

Euler Angle

$$\mathbf{R}_{wvw}(\theta_1\,\theta_2\,\theta_3) = \mathbf{R}_w(\theta_1)\,\mathbf{R}_{v'}(\theta_2)\,\mathbf{R}_{w''}(\theta_3)$$
$$= \begin{bmatrix} C_1C_2C_3 - S_1S_3 & -C_1C_2S_3 - S_1C_3 & C_1S_2 \\ S_1C_2C_3 + C_1S_3 & -S_1C_2S_3 + C_1C_3 & S_1S_2 \\ -S_2C_3 & S_2S_3 & C_2 \end{bmatrix}$$

Euler Parameter

$$\begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} = \begin{bmatrix} 1-2\varepsilon_2^2-2\varepsilon_3^2 & 2(\varepsilon_1\varepsilon_2-\varepsilon_3\varepsilon_0) & 2(\varepsilon_1\varepsilon_3+\varepsilon_2\varepsilon_0) \\ 2(\varepsilon_1\varepsilon_2+\varepsilon_3\varepsilon_0) & 1-2\varepsilon_1^2-2\varepsilon_3^2 & 2(\varepsilon_2\varepsilon_3-\varepsilon_1\varepsilon_0) \\ 2(\varepsilon_1\varepsilon_3-\varepsilon_2\varepsilon_0) & 2(\varepsilon_2\varepsilon_3+\varepsilon_1\varepsilon_0) & 1-2\varepsilon_1^2-2\varepsilon_2^2 \end{bmatrix}$$