NPTEL Course

Robotics and Control: Theory and Practice

Assignment 2

1. If a point p(x,y,z) in a coordinate frame rotates about the z−axis with angular velocity 0.01 rad. per second, then:
   a. $\dot{x} = 0.01y,\ \dot{y} = -0.01x$
   b. $\dot{x} = -0.01y,\ \dot{y} = 0.01x$
   c. $\dot{x} = -0.01x,\ \dot{y} = 0.01y$
   d. $\dot{x} = 0.01x,\ \dot{y} = -0.01y$
2. If the z_{k-1} and z_k axes of a robot joint coordinate frames are non intersecting then:
   a. x_k is the common normal to z_{k-1} and z_k.
   b. x_{k-1} is the common normal to z_{k-1} and z_k.
   c. y_k is parallel to z_{k-1}.
   d. y_{k-1} is parallel to z_{k-1}.
3. If ${}^{i-1}T_i : i = 1,2, \dots \dots n$ denotes ith coordinate frame with respect to $i - 1^{th}$ coordinate frame of a n dof manipulator, then the k^{th} column of the Jacobian matrix is obtained using:
   a. ${}^{0}T_k$
   b. ${}^{k}T_n$
   c. ${}^{k-1}T_k$
   d. ${}^{k-1}T_n$
4. The homogeneous transformation matrix representing the k^{th} joint frame with respect to $k{-}1^{th}$ joint frame of a robot manipulator is given by ${}^{k-1}T_k$=:
   a. $\begin{bmatrix} \cos\theta_k & -\cos\alpha_k \sin\theta_k & \sin\alpha_k \sin\theta_k & a_k \cos\theta_k \\ \sin\theta_k & \cos\alpha_k \cos\theta_k & -\sin\alpha_k \cos\theta_k & a_k \sin\theta_k \\ 0 & \sin\alpha_k & \cos\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$

   b. $\begin{bmatrix} \cos\theta_k & \cos\alpha_k \sin\theta_k & \sin\alpha_k \sin\theta_k & a_k \cos\theta_k \\ \sin\theta_k & -\cos\alpha_k \cos\theta_k & -\sin\alpha_k \cos\theta_k & a_k \sin\theta_k \\ 0 & \sin\alpha_k & \cos\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$
   c. $\begin{bmatrix} \cos\theta_k & -\cos\alpha_k \sin\theta_k & -\sin\alpha_k \sin\theta_k & a_k \cos\theta_k \\ \sin\theta_k & \cos\alpha_k \cos\theta_k & \sin\alpha_k \cos\theta_k & a_k \sin\theta_k \\ 0 & \sin\alpha_k & \cos\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$
   d. $\begin{bmatrix} \cos\theta_k & -\cos\alpha_k \sin\theta_k & \sin\alpha_k \sin\theta_k & a_k \cos\theta_k \\ \sin\theta_k & \cos\alpha_k \cos\theta_k & -\sin\alpha_k \cos\theta_k & a_k \sin\theta_k \\ 0 & \cos\alpha_k & \sin\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$

5. Kinematic equations of a 3 axis manipulator are given as:

$$x = [L_2 \cos\theta_2 + L_3 \cos(\theta_2 + \theta_3)]cos\theta_1$$
$$y = [L_2 \cos\theta_2 + L_3 \cos(\theta_2 + \theta_3)]sin\theta_1$$
$$z = L_1 + L_2 \sin\theta_2 + L_3 \sin(\theta_2 + \theta_3)$$

Then $\cos\theta_3$ is:

a. $\frac{x^2+y^2+(z-l_1)^2-l_2^2-l_3^2}{-2l_2l_3}$

b. $\frac{x^2+y^2+(z-l_1)^2-l_2^2-l_3^2}{2l_2l_3}$

c. $\frac{x^2+y^2+(z-l_1)^2+l_2^2-l_3^2}{-2l_2l_3}$

d. $\frac{x^2+y^2+(z-l_1)^2-l_2^2+l_3^2}{-2l_2l_3}$

6. The joint co-ordinate transformations of a robot manipulator are given below:

$$^0T_1 = \begin{bmatrix} \cos\theta_1 & 0 & -\sin\theta_1 & 0 \\ \sin\theta_1 & 0 & \cos\theta_1 & 0 \\ 0 & -1 & 0 & 10 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad ^1T_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & q_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad ^2T_3 = \begin{bmatrix} \cos\theta_3 & -\sin\theta_3 & 0 & 0 \\ \sin\theta_3 & \cos\theta_3 & 0 & 0 \\ 0 & 0 & 1 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}, 0 \le q_2 \le 6$$

The arm matrix $T = \ ^0T_3 \ at \ \theta_1 = 0, q_2 = 3 \ and \ \theta_3 = \frac{\pi}{2} \ is \ given \ by$:

a. $\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3 \\ 0 & -1 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$,

b. $\begin{bmatrix} -1 & 0 & 0 & 3 \\ 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & -5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

c. $\begin{bmatrix} 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & 3 \\ 0 & 0 & -1 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

d. $\begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & -5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

7. $\frac{\partial T}{\partial q_2}$ in (6) for mentioned values is given by:

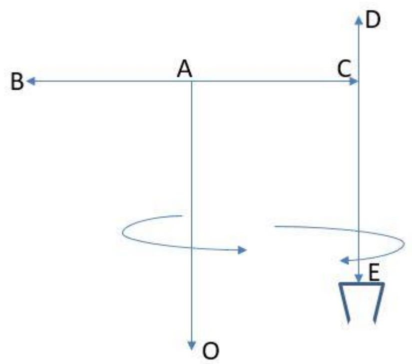
a. $\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$

b. $\begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$

c. $\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -5 \\ 0 & 0 & 0 & 0 \end{bmatrix}$

d. $\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

8. Second column of manipulator jacobian in (6) for mentioned values is given by:
   a. $[0 - 1\ 0\ 0\ 0\ 0]^T$
   b. $[-1\ \ 0\ 0\ 0\ 0\ 0]^T$
   c. $[0\ 1\ 0\ 0\ 0\ 0]^T$
   d. $[1\ 0\ 0\ 0\ 0\ 0]^T$
9. For the manipulator shown below, OA=15, BC=10, DE=15.



If the position and orientation of the end-effector E with respect to base O is given by:

$$\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 4 \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 3 \\ 0 & 0 & -1 & 9 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

What is value of $\theta_1 + \theta_4$. Here O and E are revolute joints and A and C are

Prismatic?

   a. $\frac{\pi}{4}$
   b. $\frac{\pi}{2}$
   c. $-\frac{\pi}{4}$
   d. $-\frac{\pi}{2}$
10. In previous question (9), distance variables $d_2\ and\ d_3$ are:
   a. 5 & 6 respectively
   b. 5 & 9 respectively
   c. 4 & 6 respectively
   d. 4 & 9 respectively