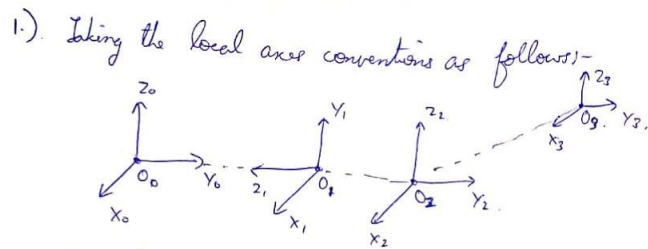


Introduction to Robotics

Assignment 2

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Solution 1



D-H parameters :-

	a_i	α_i	θ_i	d_i
1	0	90°	θ_1	0
2	0	-90°	θ_2	$-l_2$
3	0	0	0	d_3

Here, $O_0 = O_1 = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$; $O_2 = \begin{bmatrix} -l_2 s_1 \\ l_2 c_1 \\ 0 \end{bmatrix}$; $O_3 = \begin{bmatrix} -d_3 c_1 s_2 - l_2 s_1 \\ -d_3 s_1 s_2 + l_2 c_1 \\ c_2 d_3 \end{bmatrix}$

$z_0 = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$; $z_1 = \begin{bmatrix} s_1 \\ c_1 \\ 0 \end{bmatrix}$; $z_2 = \begin{bmatrix} -c_1 s_2 \\ -s_1 s_2 \\ c_2 \end{bmatrix}$; $z_3 = z_2$

Now, Jacobian, $J = \begin{bmatrix} z_0 \times (O_3 - O_0) & z_1 \times (O_3 - O_1) & z_2 \\ z_0 & z_1 & 0 \end{bmatrix}$

i.e. $J = \begin{bmatrix} d_3 s_1 s_2 - l_2 c_1 & -c_1 c_2 d_3 & -c_1 s_2 \\ -d_3 c_1 s_2 - l_2 s_1 & -s_1 c_2 d_3 & -s_1 s_2 \\ 0 & -d_3 s_2 & c_2 \\ 0 & s_1 & 0 \\ 0 & -c_1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$

Now, given : $v = \begin{bmatrix} 10 \\ 10 \\ 5 \end{bmatrix}$; $d_3 = 10$; $h_2 = 2$; $\varepsilon_1 = \begin{bmatrix} v \\ 10 \end{bmatrix}$.

We get, $J = \begin{bmatrix} 5/\sqrt{2} - \sqrt{3} & -5\sqrt{3}/\sqrt{2} & -\sqrt{3}/2\sqrt{2} \\ -5\sqrt{3}/2 & -1 & -5/\sqrt{2} \\ 0 & -5/\sqrt{2} & 1/\sqrt{2} \\ 0 & 1/2 & 0 \\ 0 & \sqrt{3}/2 & 0 \\ 1 & 0 & 0 \end{bmatrix}$

$$Jq' = \varepsilon_1 = J \begin{bmatrix} q'_1 \\ q'_2 \\ d'_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 10 \\ 5 \\ \omega \end{bmatrix}$$

From this, $(5/\sqrt{2} - \sqrt{3}) q'_1 - 5\sqrt{3}/\sqrt{2} q'_2 - \sqrt{3}/2\sqrt{2} d'_3 = 10$ — (1)

$$(-5\sqrt{3}/2 - 1) q'_1 - 5/\sqrt{2} q'_2 - 1/2\sqrt{2} d'_3 = 10$$
 — (2)

$$-5\sqrt{2} q'_2 + d'_3/\sqrt{2} = 5$$
 — (3)

From (1), (2), (3), we obtain.

$$q'_1 = -0.517$$

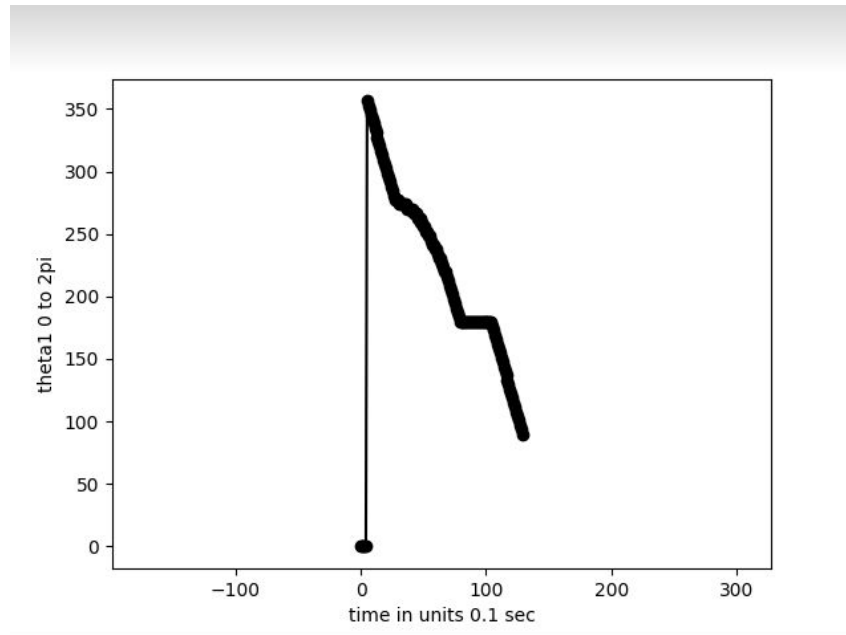
$$q'_2 = -1.246$$

$$d'_3 = -5.39$$

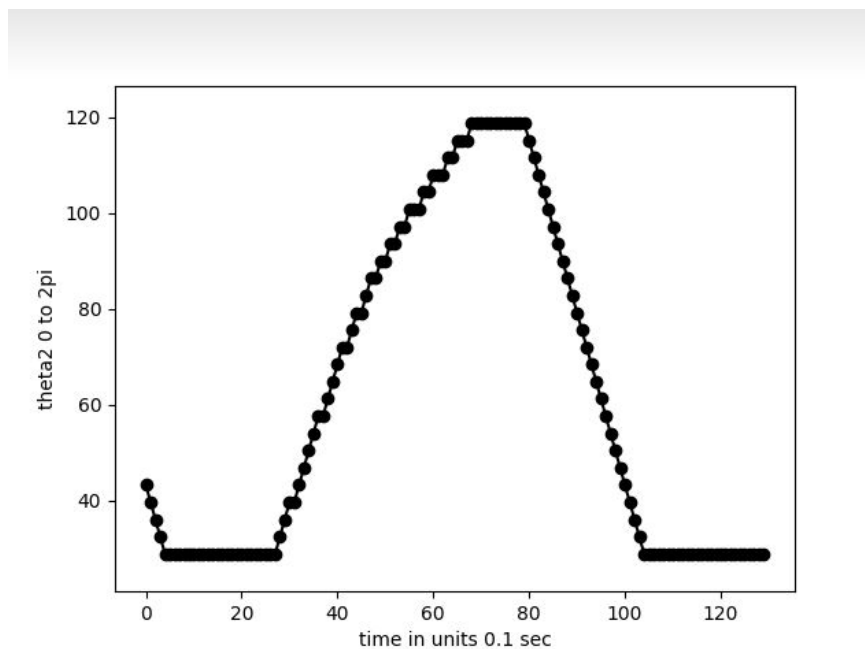
Solution 2

The required code has been attached as “Q2.py”. The required [plots are as follows:

For Angle 1, (first junction):



For Angle 2, (Junction between a1 and a2):



Solution 3

An obtained constant acceleration path for the given setup is as follows:

