Homework-4

ENPM662: Introduction to Robot Modelling

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1.1) D-H Table without end effector pen

links	a_i	α_i	d_i	θ_i
0-1	0	90	128	θ_0+180
1-2	-612.7	180	0	$\theta_1 - 90$
2-3	-571.6	180	0	θ_2
3-4	0	-90	163.9	$\theta_3 + 90$
4-5	0	90	115.7	θ_4
5-E	0	0	92.2	θ_5

1.2) D-H Table with end effector pen

links	a_i	α_i	d_i	θ_i
0-1	0	90	128	θ_0+180
1-2	-612.7	180	0	$\theta_1 - 90$
2-3	-571.6	180	0	θ_2
3-4	0	-90	163.9	$\theta_3 + 90$
4-5	0	90	115.7	θ_4
5-E	0	0	192.2	θ_5

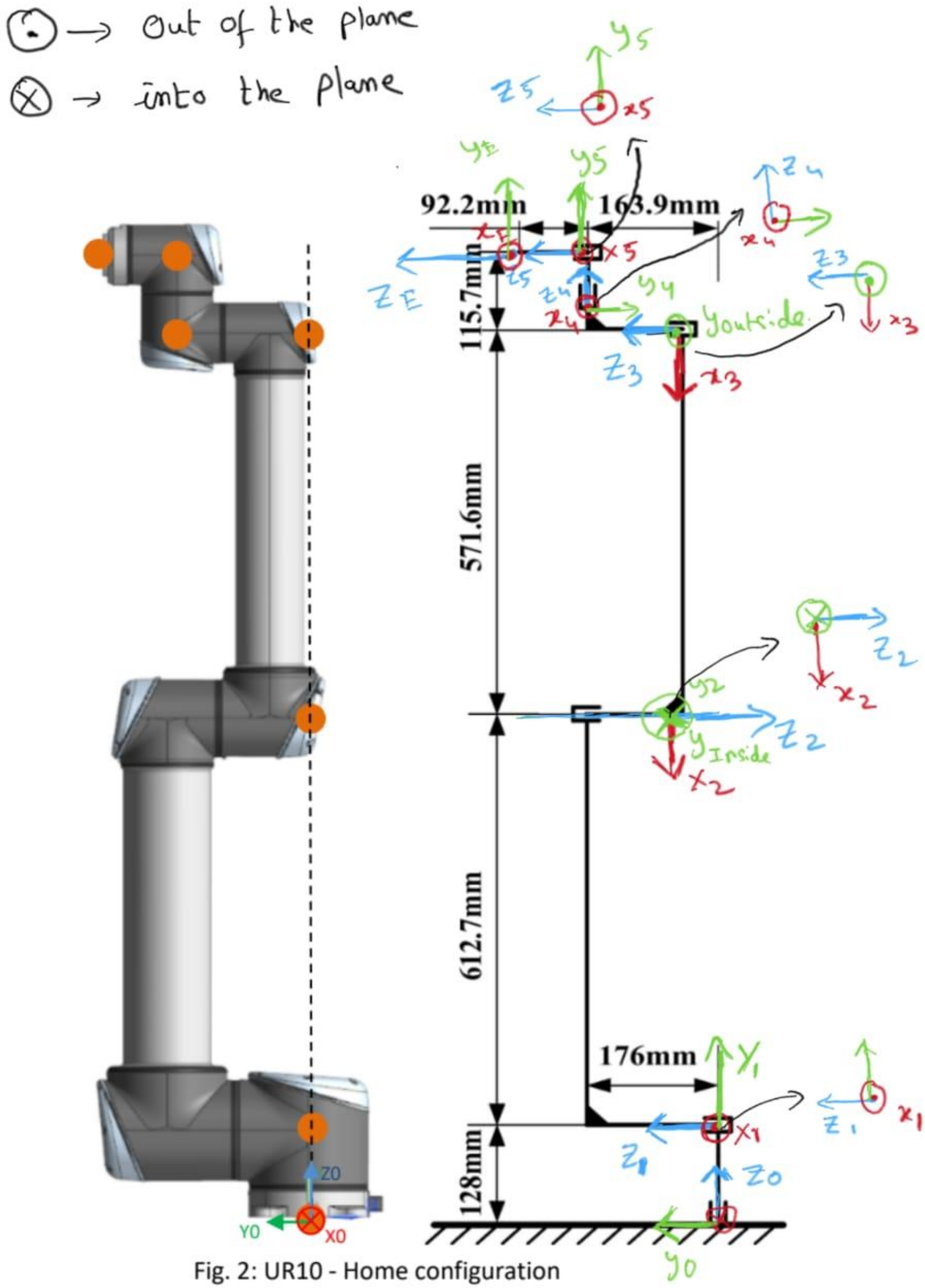


Fig. 2: UR10 - Home configuration

Part 1: To find Jacobian matrix I followed method one :

$$J_v = [J_{v1} .....J_{v_n}]$$
$$J_{v_i} = R_{i-1} \times (o_n - o_{i-1})$$
$$J_w = [J_{w_1} ....J_{w_n}]$$
$$J_{w_i} = R_{i-1}$$

$$J_i = \begin{bmatrix} z_{i-1} \times (o_n - o_{i-1}) \\ z_{i-1} \end{bmatrix}$$

$$J = \begin{bmatrix} J_v \\ J_\omega \end{bmatrix}$$

So the following will be the J matrix

$$J = \begin{bmatrix} R_0^0 \begin{bmatrix}0\\0\\1\end{bmatrix} (o_6^0 - o_0^0) & R_1^0 \begin{bmatrix}0\\0\\1\end{bmatrix} (o_6^0 - o_1^0) & R_2^0 \begin{bmatrix}0\\0\\1\end{bmatrix} (o_6^0 - o_2^0) & R_3^0 \begin{bmatrix}0\\0\\1\end{bmatrix} (o_6^0 - o_3^0) & R_4^0 \begin{bmatrix}0\\0\\1\end{bmatrix} (o_6^0 - o_4^0) & R_5^0 \begin{bmatrix}0\\0\\1\end{bmatrix} (o_6^0 - o_5^0) \\ R_0^0 \begin{bmatrix}0\\0\\1\end{bmatrix} & R_1^0 \begin{bmatrix}0\\0\\1\end{bmatrix} & R_2^0 \begin{bmatrix}0\\0\\1\end{bmatrix} & R_3^0 \begin{bmatrix}0\\0\\1\end{bmatrix} & R_4^0 \begin{bmatrix}0\\0\\1\end{bmatrix} & R_5^0 \begin{bmatrix}0\\0\\1\end{bmatrix} \end{bmatrix}$$

Part 2 : Defining velocity matrix

$$\xi = \begin{bmatrix} v_n^0 \\ \omega_n^0 \end{bmatrix}$$

Where in our case Vn will be vector of Vx, Vy, Vz and Wn will be Wx, Wy, Wz

Since our end effector is moving in a single plane of z-x the remaining all the terms of Vn and Wn will be zero except Vx and Vz.

So in our case we need to plot circle, by the parametric equations of circle we get the following equation

$$x = r.cos\theta, z = r.sin\theta$$
$$\dot{x} = r.cos\theta.\dot{\theta}, \dot{z} = r.sin\theta.\dot{\theta}$$

Where dθ/dt = angular velocity which is equal to 2*π / 20 since it is required to complete the circle in 20 seconds

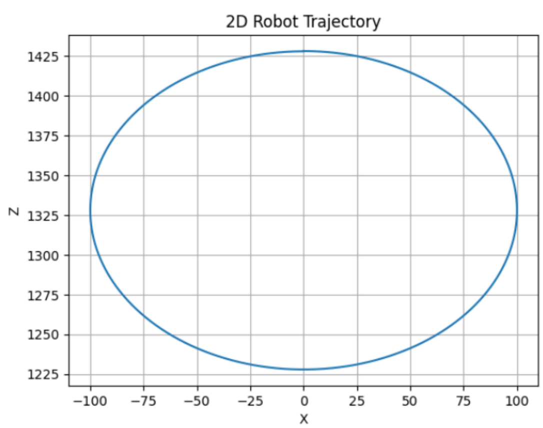
So using this method we get velocity matrix as

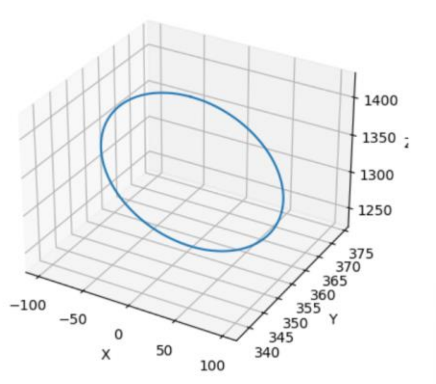
$$E = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \\ \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}$$

Now using inverse kinematics method

$$E = J \cdot \dot{q}$$
$$\dot{q} = J^{-1} \cdot E$$

Results: Implementing the above two methods in the code we get the following final plot of circle in both 2D and 3D plots





3-D trajectory

Here is the code file in google collab

https://colab.research.google.com/drive/1cwnwz7Ii0SKXWeUeUjYhQm3urDsmj8RB?usp=sharing