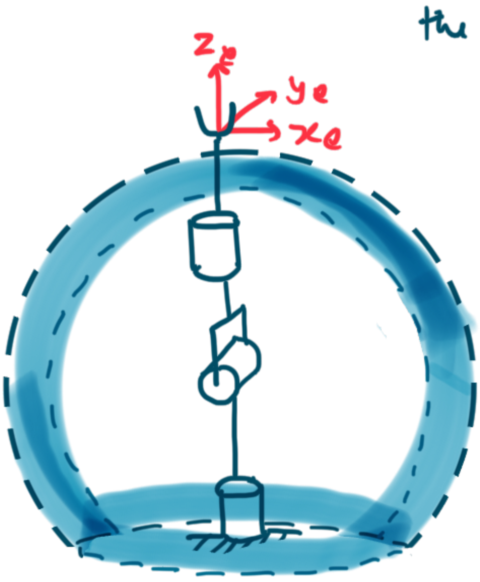
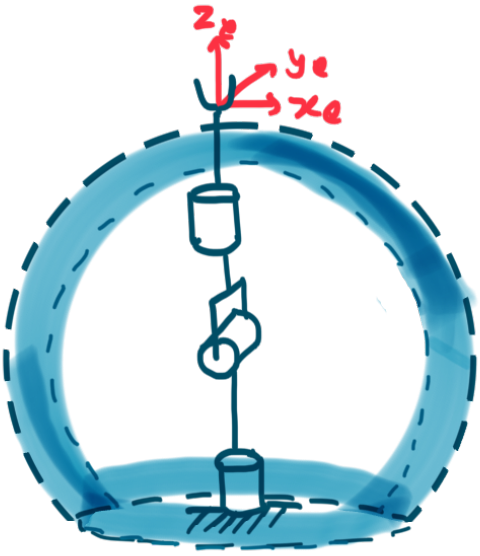
Prelab 1

1. Dextrous workspace – points the manipulator can reach with an arbitrary orientation of the end effector



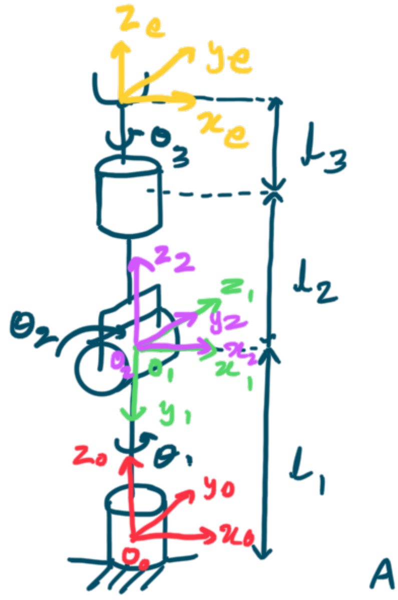
Dextrous Workspace

2. Reachable Workspace – Full set of points the manipulator can reach.



Here the dextrous & reachable workspace is the same

3.



Link	a_i	α_i	d_i	θ_i
1	0	$-90°$	l_1	θ_1
2	0	$90°$	0	θ_2
3	0	0	l_2+l_3	θ_3

$$A_i = \begin{bmatrix} c\theta_i & -s\theta_i c_{\alpha_i} & s\theta_i s_{\alpha_i} & a_i c\theta_i \\ s\theta_i & c\theta_i c_{\alpha_i} & -c\theta_i s_{\alpha_i} & a_i s\theta_i \\ 0 & s_{\alpha_i} & c_{\alpha_i} & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_1 = \begin{bmatrix} c\theta_1 & 0 & -s\theta_1 & 0 \\ s\theta_1 & 0 & c\theta_1 & 0 \\ 0 & -1 & 0 & l_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} c\theta_3 & -s\theta_3 & 0 & 0 \\ s\theta_3 & c\theta_3 & 0 & 0 \\ 0 & 0 & 1 & l_2+l_3 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} c\theta_2 & 0 & s\theta_2 & 0 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} c\theta_2 & 0 & s\theta_2 & 0 \\ s\theta_2 & 0 & -c\theta_2 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 0 & 0 & 0 & 0 \end{bmatrix}$$

$$T_3^0 = A_1 A_2 A_3$$

$$= \left[\begin{array}{c|c|c|c} c\theta_1 c\theta_2 c\theta_3 - s\theta_1 s\theta_3 & -c\theta_1 c\theta_2 s\theta_3 - s\theta_1 c\theta_3 & c\theta_1 s\theta_2 & (l_2+l_3)c\theta_1 s\theta_2 \\ s\theta_1 c\theta_2 c\theta_3 + c\theta_1 s\theta_3 & -s\theta_1 c\theta_2 s\theta_3 + c\theta_1 c\theta_3 & s\theta_1 s\theta_2 & (l_2+l_3)s\theta_1 s\theta_2 \\ -s\theta_2 c\theta_3 & s\theta_2 s\theta_3 & c\theta_2 & (l_2+l_3)c\theta_2 + l_1 \\ 0 & 0 & 0 & 1 \end{array}\right]$$

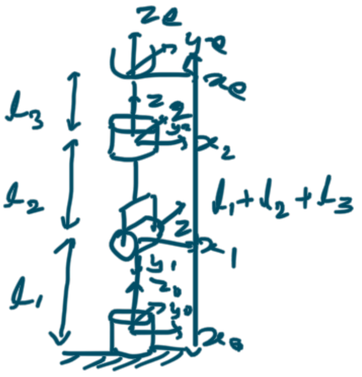
4. Process used: Forward Kinematics. The joint axes are labeled $z_0 \dots z_{n-1}$. The x_0, y_0 location is set as per RHR. We locate O_i where the common normal to z_i & z_{i-1} intersects z_i. Then the DH parameters are set as per the given rules. A_i is substituted & intermediate transformations are found. From $T_n^0 = A_1 A_2 \cdots A_n$, we get the position & orientation of the end effector in the base frame.

5. Eg 1: $\theta = [0° \; 0° \; 0]$, $\theta = \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$

$P = T_e^0 \theta$

$$P = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & l_1+l_2+l_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ l_1+l_2+l_3 \\ 1 \end{bmatrix}$$

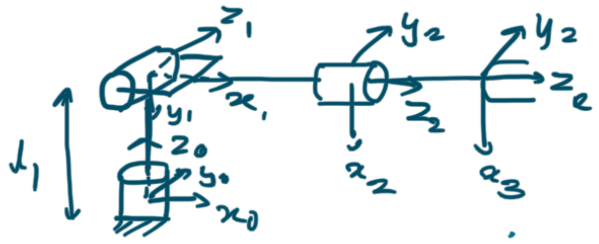
→ This result makes sense because the robot is in home configuration, & the net displacement is the full extended length in the z direction of the base frame.



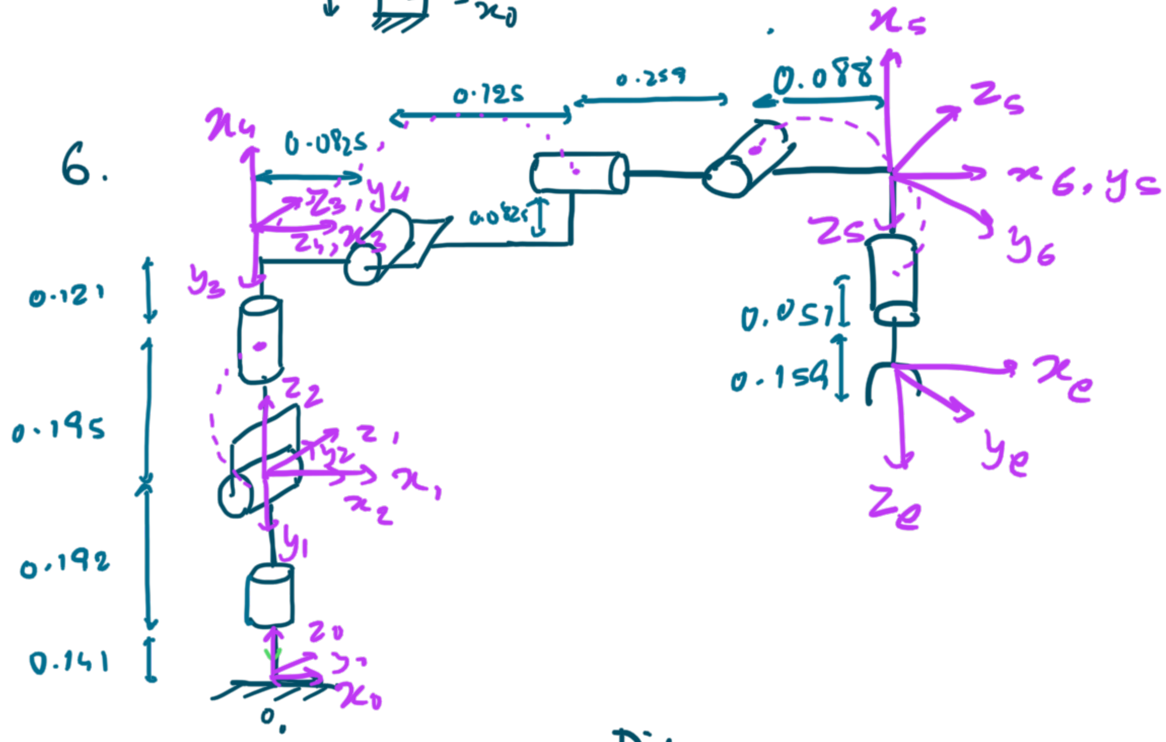
Eg 2: $\theta = [0 \quad 90 \quad 0]$ $\quad \theta = \begin{bmatrix} 0 \\ 90 \\ 0 \\ 1 \end{bmatrix}$

$$P = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & l_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

→ This result makes sense because the effective translation from the base frame is l_1 in the z direction in this configuration. The orientation of E.E w.r.t base is also ideal.



6.



Differences:

1. The PANDA arm has 7 DOF while the previous robot has 3DOF
2. The 2 robots have different workspaces.