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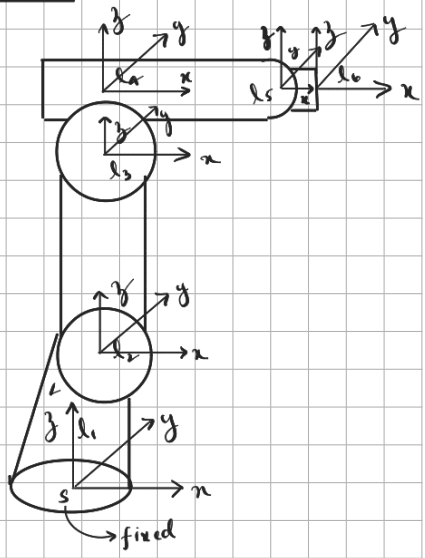
Problem 2) ABB IRB 620



General forward kinematics

$$g_{sl_1} = \begin{bmatrix} R_z q_1 & p_{l_1} \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} \cos q_1 & -\sin q_1 & 0 & 0 \\ \sin q_1 & \cos q_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$g_{l_1 l_2} = \begin{bmatrix} R_y q_2 & p_{l_1 l_2} \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} \cos q_2 & 0 & \sin q_2 & l_{x_2} \\ 0 & 1 & 0 & 0 \\ -\sin q_2 & 0 & \cos q_2 & l_{z_2} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$g_{l_2 l_3} = \begin{bmatrix} R_y q_3 & p_{l_2 l_3} \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} \cos q_3 & 0 & \sin q_3 & 0 \\ 0 & 1 & 0 & 0 \\ -\sin q_3 & 0 & \cos q_3 & l_{z_3} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

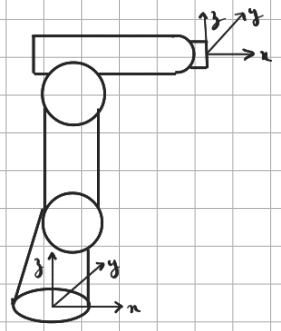
$$g_{l_3 l_4} = \begin{bmatrix} R_x q_4 & p_{l_3 l_4} \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos q_4 & -\sin q_4 & 0 \\ 0 & \sin q_4 & \cos q_4 & l_{z_4} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$g_{l_4 l_5} = \begin{bmatrix} R_y q_5 & p_{l_4 l_5} \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} \cos q_5 & 0 & \sin q_5 & l_{x_5} \\ 0 & 1 & 0 & 0 \\ -\sin q_5 & 0 & \cos q_5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$g_{l_5 l_6} = g_{l_5 t} = \begin{bmatrix} R_x q_6 & p_{l_5 l_6} \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & l_{x_6} \\ 0 & \cos q_6 & -\sin q_6 & 0 \\ 0 & \sin q_6 & \cos q_6 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Now, $g_{st} = g_{sl_1}\ g_{l_1 l_2}\ g_{l_2 l_3}\ g_{l_3 l_4}\ g_{l_4 l_5}\ g_{l_5 t}$

Power of exponents method



For $g_{st}(0) \Rightarrow R_{st}(0) = R_y(0) = I_{3\times3}$

$$p_{st}(0) = [(320+387+200) \quad 0 \quad (630+975+200)]^T$$

$$= [1907 \quad 0 \quad 1855]^T$$

$$\Rightarrow g_{st}(0) = \begin{bmatrix} 1 & 0 & 0 & 1907 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1855 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\xi_i = [-\omega_i \times p_i \quad \omega_i]^T$$

In reference configuration:

ξ_1: $\omega_1 = [0 \quad 0 \quad 1]^T$; $p_1 = [0 \quad 0 \quad 0]^T$

$\Rightarrow \xi_1 = [0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1]^T$

ξ_2: $\omega_2 = [0 \quad 1 \quad 0]^T$; $p_2 = [320 \quad 0 \quad 630]^T$

$\Rightarrow \xi_2 = [-630 \quad 0 \quad 320 \quad 0 \quad 1 \quad 0]^T$

ξ_3: $\omega_3 = [0 \quad 1 \quad 0]^T$; $p_3 = [320 \quad 0 \quad 1655]^T$

$\xi_3 = [-1655 \quad 0 \quad 320 \quad 0 \quad 1 \quad 0]^T$

ξ_4: $\omega_4 = [1 \quad 0 \quad 0]^T$; $p_4 = [320 \quad 0 \quad 1855]^T$

$\xi_4 = [0 \quad 1855 \quad 0 \quad 1 \quad 0 \quad 0]^T$

ξ_5: $\omega_5 = [0 \quad 1 \quad 0]^T$; $p_5 = [1207 \quad 0 \quad 1855]^T$

$\xi_5 = [-1855 \quad 0 \quad 1207 \quad 0 \quad 1 \quad 0]^T$

ξ_6: $\omega_6 = [1 \quad 0 \quad 0]^T$; $p_6 = [1907 \quad 0 \quad 1855]^T$

$\xi_6 = [0 \quad 1855 \quad 0 \quad 1 \quad 0 \quad 0]^T$

Now, $g_{st} = \xi_1 \xi_2 \xi_3 \xi_4 \xi_5 \xi_6 g_{st}(0)$