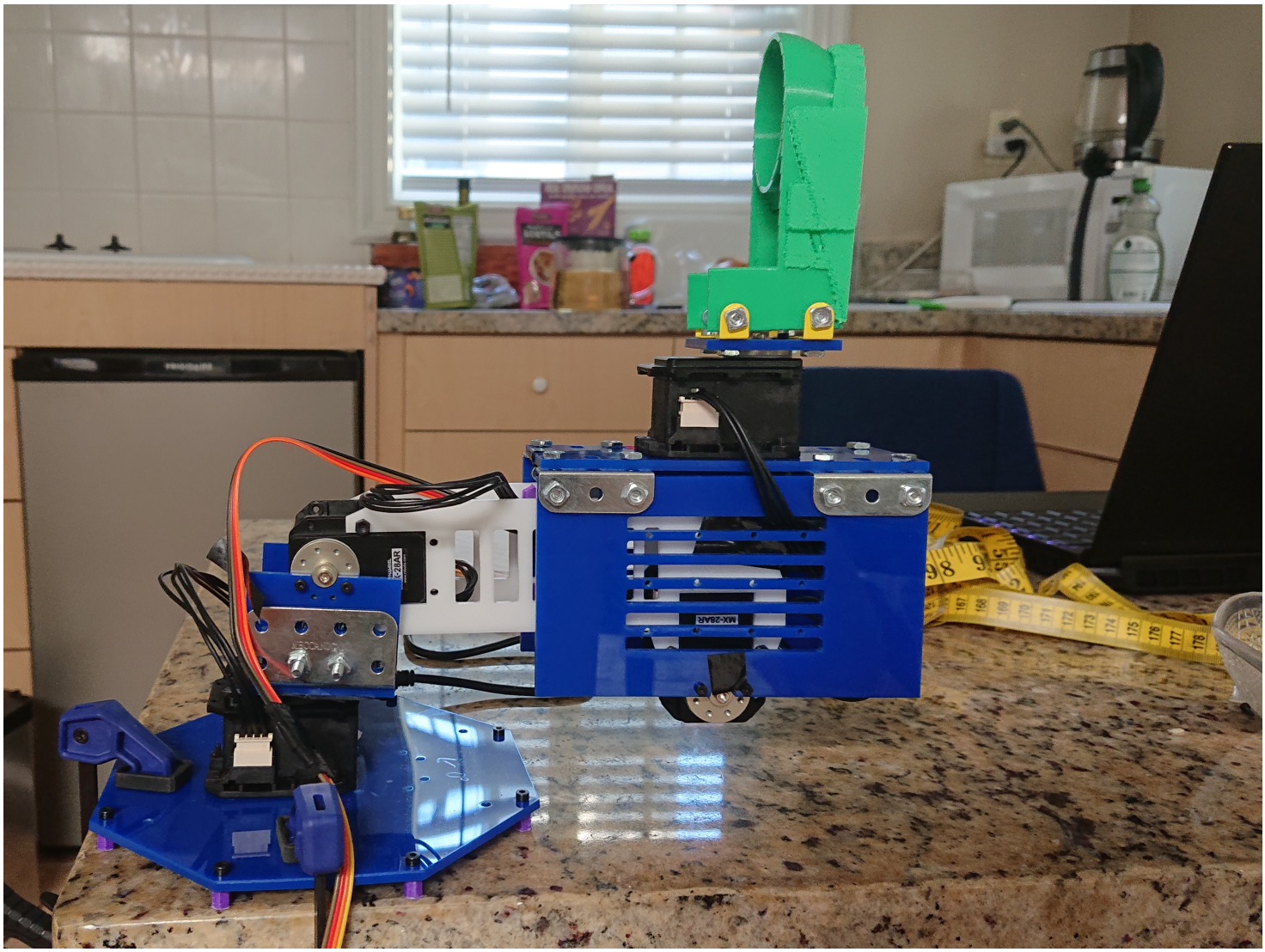
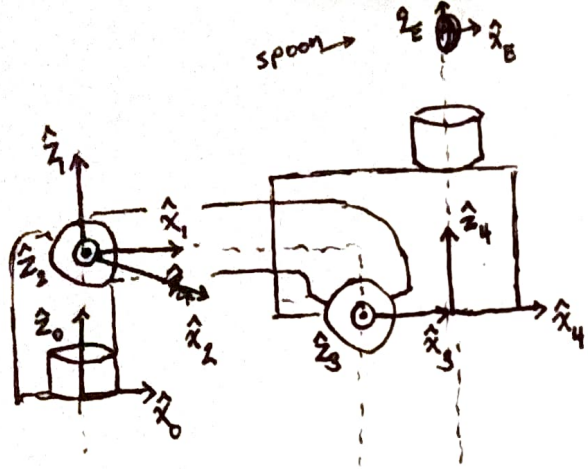

MX-28AR



$$ {}^0_1T = \begin{bmatrix} c_1 & -s_1 & 0 & 0 \\ s_1 & c_1 & 0 & 0 \\ 0 & 0 & 1 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad {}^1_2T = \begin{bmatrix} c_2 & -s_2 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ s_2 & c_2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^2_3T = \begin{bmatrix} c_3 & -s_3 & 0 & L_2 \\ s_3 & c_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad {}^3_4T = \begin{bmatrix} c_4 & -s_4 & 0 & L_3 \\ 0 & 0 & 1 & 0 \\ -s_4 & -c_4 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^4_ET = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_E \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$i-1$	i	α_{i-1}	a_{i-1}	d_i	θ_i
0	1	0	0	d_1	θ_1
1	2	90°	0	0	θ_2
2	3	0°	L_2	0	θ_3
3	4	-90°	L_3	0	θ_4
4	E	0°	0	d_E	0°

$$ {}^0_ET = \begin{bmatrix} c_1c_4c_{23} - s_1s_4 & -s_1c_4 - c_1s_4c_{23} & -c_1s_{23} & (L_2c_2 + L_3c_{23} - d_Es_{23})c_1 \\ c_1s_4 + s_1c_4c_{23} & c_1c_4 - s_1s_4c_{23} & -s_1s_{23} & (L_2c_2 + L_3c_{23} - d_Es_{23})s_1 \\ c_4s_{23} & -s_4s_{23} & c_{23} & d_1 + L_2s_2 + L_3s_{23} + d_Ec_{23} \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

θ_1: If $p_x, p_y \neq 0$: $\theta_1 = \text{atan2}(p_y, p_x)$

Elseif $r_{13}, r_{23} \neq 0$: $\theta_1 = \text{atan2}(-r_{23}, -r_{13})$

Else (singularity, $c_{23} = \pm 1$)

- $c_{23} = +1$: $\theta_1 + \theta_4 = \text{atan2}(r_{21}, r_{11})$
- $c_{23} = -1$: $\theta_4 - \theta_1 = \text{atan2}(r_{21}, -r_{11})$

θ_4: If $r_{31}, r_{32} \neq 0$: $\theta_4 = \text{atan2}(-r_{32}, r_{31})$

Else (singularity, $c_{23} = \pm 1$)

$\theta_2 + \theta_3$:

$$ s_{23} = -\text{sign}(r_{13}) \cdot \text{sign}(c_1) \cdot \sqrt{r_{13}^2 + r_{23}^2} \rightarrow \theta_2 + \theta_3 = \text{atan2}\left(-\text{sign}(r_{13}) \cdot \text{sign}(c_1) \sqrt{r_{13}^2 + r_{23}^2},\ r_{33}\right) $$

$$ = -\text{sign}(r_{23}) \cdot \text{sign}(s_1) \cdot \sqrt{r_{13}^2 + r_{23}^2} \qquad = \text{atan2}\left(-\text{sign}(r_{23}) \cdot \text{sign}(s_1) \sqrt{r_{13}^2 + r_{23}^2},\ r_{33}\right) $$

If c_1 or $s_1 = 0$ use the other.

Alternatively : $s_{23} = -r_{13}/c_1$ or $-r_{23}/s_1$ $\rightarrow$ $\theta_2 + \theta_3 = \begin{matrix} \text{atan2}\left(-\frac{r_{13}}{c_1},\ r_{33}\right) \\ \text{atan2}\left(-\frac{r_{23}}{s_1},\ r_{33}\right) \end{matrix}$ ← easier to code.

θ_2: $\theta_2 =$

$$ \text{atan2}\left(p_z - d_Ec_{23} - L_3s_{23} - d_1,\ p_x/c_1 + d_Es_{23} - L_3c_{23}\right) $$

$$ \text{atan2}\left(p_z - d_Ec_{23} - L_3s_{23} - d_1,\ p_y/s_1 + d_Es_{23} - L_3c_{23}\right) $$

θ_3: $\theta_3 = (\theta_2 + \theta_3) - \theta_2$