MANIP Lab report (M1 CORO/JEMARO)

Joseph Webb - Thursday 17 November 2022

1 Modified DH-Tables

1.1 Turret Robot

$r_1 = 0.5, \quad r_2 = 0.1$

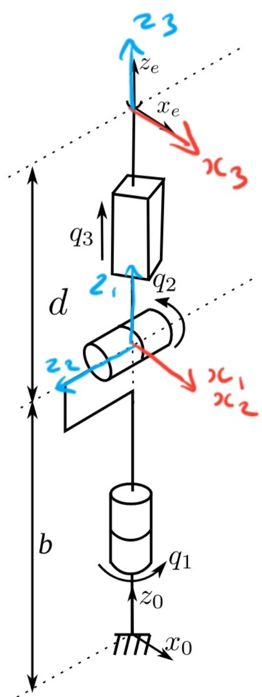

Figure 1: schematic of turret robot with intermediary frames

Joint	a	α	θ	r
1	0	0	q_1	b
2	0	$\pi/2$	q_2	0
3	0	$-\pi/2$	0	$q_3 + d$
e	0	0	0	0

Table 1: Modified DH-table for turret bot

1.2 KR-16 Robot (KUKA)

$r_1 = 0.675, \quad r_2 = 0.26, \quad r_3 = 0.68, \quad r_4 = 0.035, \quad r_5 = 0.67, \quad r_e = 0.158$

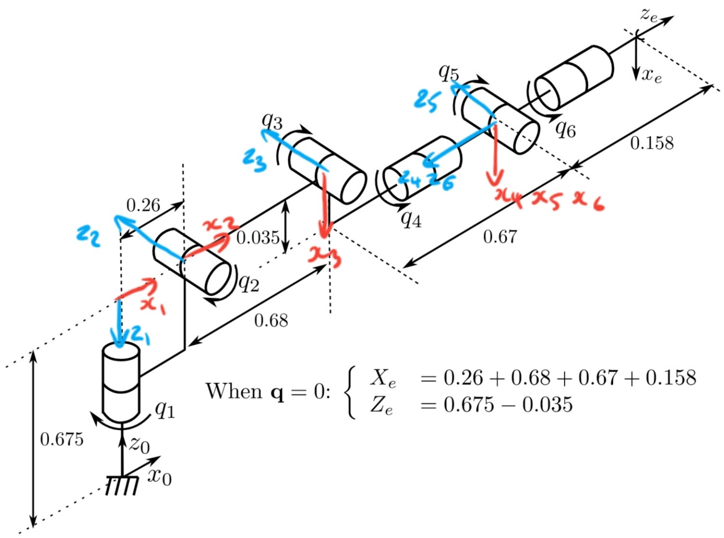

Figure 2: schematic of KUKA with intermediary frames

Joint	a	α	θ	r
1	0	π	q_1	$-r_1$
2	r_2	$\pi/2$	q_2	0
3	r_3	0	$q_3 + \pi/2$	0
4	r_4	$-\pi/2$	q_4	$-r_5$
5	0	$\pi/2$	q_5	0
6	0	$-\pi/2$	q_6	0
e	0	π	0	r_e

Table 2: Modified DH-table for KUKA

1.3 UR-10 Robot

$r_1 = 0.1273, \quad r_2 = 0.612, \quad r_3 = 0.5723, \quad r_4 = 0.1639, \quad r_5 = 0.1157, \quad r_e = 0.1922$

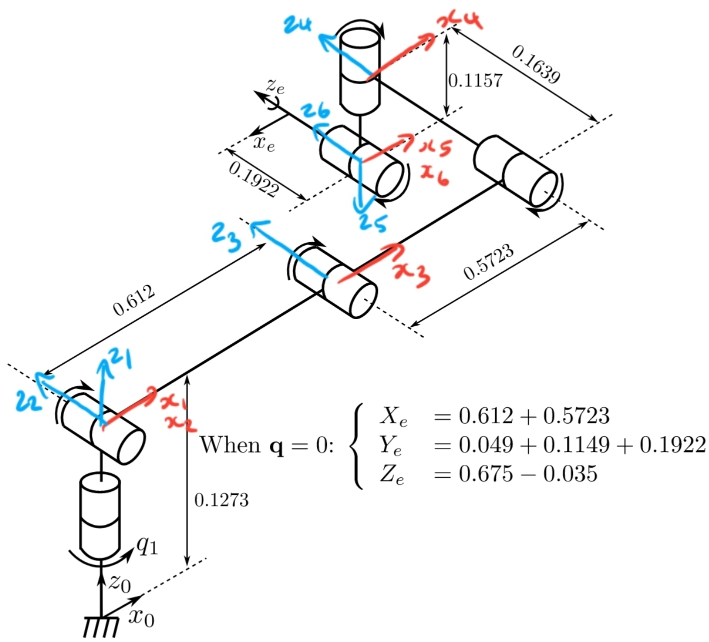

Figure 3: schematic of UR10 with intermediary frames

Joint	a	α	θ	r
1	0	0	q_1	r_1
2	0	$-\pi/2$	q_2	0
3	r_2	0	q_3	0
4	r_3	0	q_4	r_4
5	0	$-\pi/2$	q_5	r_5
6	0	$\pi/2$	q_6	0
e	0	0	π	r_e

Table 3: Modified DH-table for UR-10

2 Inverse Geometric Models

2.1 Turret Robot

$$^{f}M_w = \begin{pmatrix} c_1c_2 & -s_1 & -s_2c_1 & (-q_3 - r_2)s_2c_1 \\ s_1c_2 & c_1 & -s_1s_2 & (-q_3 - r_2)s_1s_2 \\ s_2 & 0 & c_2 & r_1 + (q_3 + r_2)c_2 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} x_x & x_y & x_z & t_x \\ y_x & y_y & y_z & t_y \\ z_x & z_y & z_z & t_z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

from x_y and y_y q_1 can be computed:

$$-s_1 = x_y \quad c_1 = y_y$$
$$q_1 = \text{solveType3}(-1, 0, y_x, 0, 1, y_y) \tag{1}$$

Then, q_2 is solved in the same way:

$$q_2 = \text{solveType3}(1, 0, x_z, 0, 1, z_z) \tag{2}$$

Solving for prismatic joint 3 depends on the value of s_1 & c_1. If $c_2 \neq 0$ we can use it to solve q_3 using the following equation:

$$q_3 = \frac{t_z - r_1}{c_2} - r_2 \tag{3}$$

If $c_2 = 0$ but $s_1 \neq 0$ then s_1 can be used to solve q_3

$$q_3 = -\frac{ty}{s_1s_2} - r_1 \tag{4}$$

otherwise, if both are null, the following equation must be used:

$$q_3 = -\frac{t_x}{s_2c_1} - r_2 \tag{5}$$

2.2 KR-16 Robot (KUKA)

Because of the spherical wrist in the KUKA robot, the IGM can be simplified. First we can calculate the first 3 joint values using the translation between the base frame and the wrist frame. (t_x, t_y, t_z)

$$^{f}t_w = \begin{pmatrix} (a_2 + a_3c_2 - a_4s_{23} + r_4c_{23})c_1 \\ (-a_2 - a_3c_2 + a_4s_{23} - r_4c_{23})s_1 \\ -a_3s_2 - a_4c_{23} + r_1 - r_4s_{23} \\ 1 \end{pmatrix} = \begin{pmatrix} t_x \\ t_y \\ t_z \\ 1 \end{pmatrix}$$

using $^{f}t_w$:

$$(a_2 + a_3c_2 - a_4s_{23} + r_4c_{23}) = \frac{t_x}{c_1} = -\frac{t_y}{s_1}$$

Therefore, q1 can be solved as

$$q_1 = \text{solveType2}(t_x, t_y, 0) \tag{6}$$

and the remaining join values can be calculated with a type 7 equation.

$$q_2, q_{23} = \text{solveType7}(0, -a_3, (r_1 - t_z), (a_2 - {}^{t_x}/_{c_1}), a_4, r_4) \tag{7}$$

$$q_3 = q_{23} - q_2 \tag{8}$$

Now the rotation can be computed between the wrist frame an the end effector, involving only the last 3 remaining joints. using the equation

$$P^* = {}^f M_e^* = {}^f M_w {}^w M_e$$

we can compute:

$$ {}^0 R_3 = \begin{pmatrix} -s_{23}c_1 & -c_1 c_{23} & s_1 \\ s_1 s_{23} & s_1 c_{23} & c_1 \\ -c_{23} & s_{23} & 0 \end{pmatrix}$$

and

$$ {}^3 R_6 = {}^0 R_3^{-1} {}^f R_w = \begin{pmatrix} -s_4 s_6 + c_4 c_5 c_6 & -s_4 c_6 - s_6 c_4 c_5 & -s_5 c_4 \\ s_5 c_6 & -s_5 s_6 & c_5 \\ -s_4 c_5 c_6 - s_6 c_4 & s_4 s_6 c_5 - c_4 c_6 & s_4 s_5 \end{pmatrix} = \begin{pmatrix} x'_x & y'_x & z'_x \\ x'_y & y'_y & z'_y \\ x'_z & y'_z & z'_z \end{pmatrix}$$

The remaining joints therefore become trivial to solve.

$$q_5 = \text{solveType2}(0, 1, z'_y) \tag{9}$$

$$q_4 = \text{solveType3}(0, -s_5, z'_x, s_5, 0, z'_z) \tag{10}$$

$$q_6 = \text{solveType2}(0, s_5, x'_y) \tag{11}$$