

This report is part of Dynamics of Non Linear Robotic Systems [DNLRS] course for first year master students at Innopolis University. In this report I am working on Mitsubishi robot RV-1A. I solved both forward and inverse kinematics problems using Matlab R2021a. This report is stating the methods that I used while the code is available on GitHub.

## 1 Kinematic scheme

We can see the kinematic scheme of Mitsubishi robot RV-1A (Figure 1)

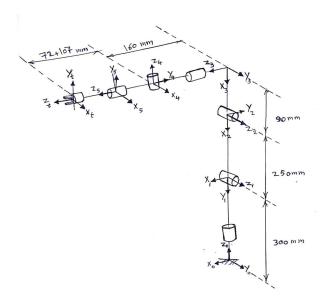


Figure 1: Mitsubishi robot RV-1A scheme.

## 2 Forward Kinematics

In order to solve the forward kinematics problem I will use Denavit Hartenberg, so first of all I need to find DH-parameters.

i	$\theta$	d	$\alpha$	a
0-1	$\theta_1$	0.3	$\frac{-\pi}{2}$	0
1-2	$\theta_2$	0	0	-0.25
2-3	$\theta_3$	0	$\frac{\pi}{2}$	-0.09
3-4	$\theta_4$	0.16	$\frac{-\pi}{2}$	0
4-5	$ heta_5$	0	$\frac{\frac{\pi}{2}}{\frac{-\pi}{2}}$ $\frac{\pi}{2}$	0
5-6	$\theta_6$	0.179	Õ	0

Table 1: DH- Parameters

Then for each joint of the robot, populate anew T matrix with the following values:

$$T_i^{i-1} = \begin{bmatrix} \cos(\theta_i) & -\sin(\theta_i) \cdot \cos(\alpha_i) & \sin(\theta_i) \cdot \sin(\alpha_i) & r \cdot \cos(theta_i) \\ \sin(\theta_i) & \cos(\theta_i) \cdot \cos(\alpha_i) & -\cos(\theta_i) \cdot \sin(\alpha_i) & r \cdot \sin(theta_i) \\ 0 & \sin(\alpha_i) & \cos(\alpha_i) & d \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Then we multiply all of the matrices together starting with the first joint all the way up to the end effector. The final T matrix will contain the position and the orientation of the end effector.

$$T_6^0 = T_1^0 \cdot T_2^1 \cdot T_3^2 \cdot T_4^3 \cdot T_5^4 \cdot T_6^5$$

## 3 Inverse Kinematics

As we know that  $q = f^{-1}(x)$ , where  $X = [P_x, P_y, P_z, \varphi, \theta, \Psi]$  and  $q = [q_1, q_2, ..., q_n]$  and we can express the final Transformation (from the first joint to the end effector) as following:

$$T_n^0 = \begin{bmatrix} s_x & n_x & a_x & p_x \\ s_y & n_y & a_y & p_y \\ s_z & n_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$
 (1)

according to the inverse Kinematic model:

$$T_6^0 = T_1^0(q_1)T_2^1(q_2)...T_6^5 (2)$$

$$T_1^0(q_1)T_6^0 = T_2^1(q_2)...T_5^4T_6^5$$
(3)

$$T_6^1(q_1) = T_6^1(q_2...q_6) - > q_1 (4)$$

when three revolute joints whose axes intersect at a point (as it happens in joints 4, 5, 6) there wont be a change in direction of the end effector while the position will be the same, so:

$$P_6^0 = P_5^0 = P_4^0 \tag{5}$$

and:

$$\begin{bmatrix} P_{x4} \\ P_{y4} \\ P_{z4} \\ 1 \end{bmatrix} = T_1^0(q_1)T_2^1(q_2)T_3^2(q_3)T_4^3(q_4) \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$
 (6)

## 4 Results

All the code is available on GitHub.