DNLRS final Project

Anthropomorphic model (ZXZ wrist configuration)

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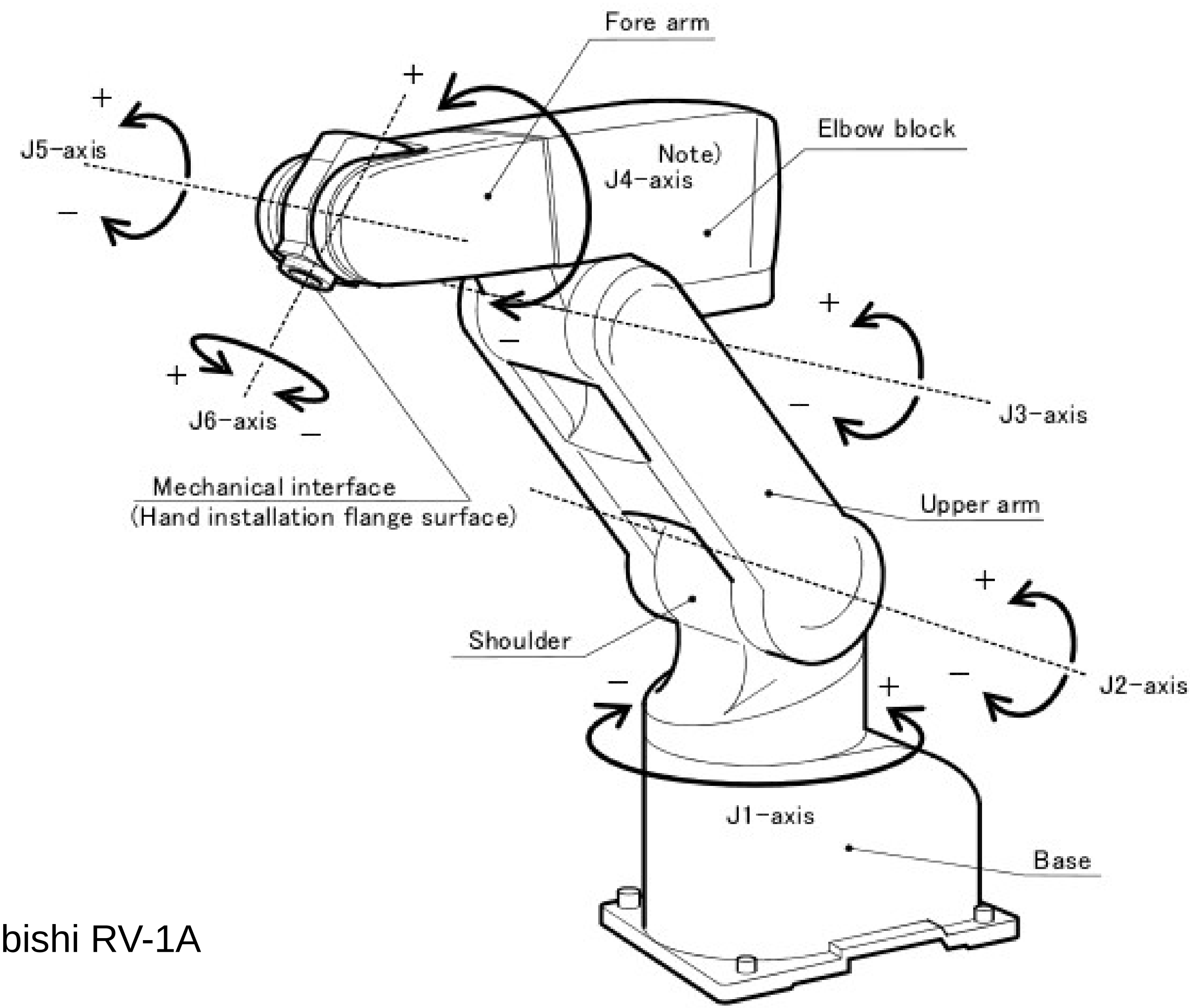
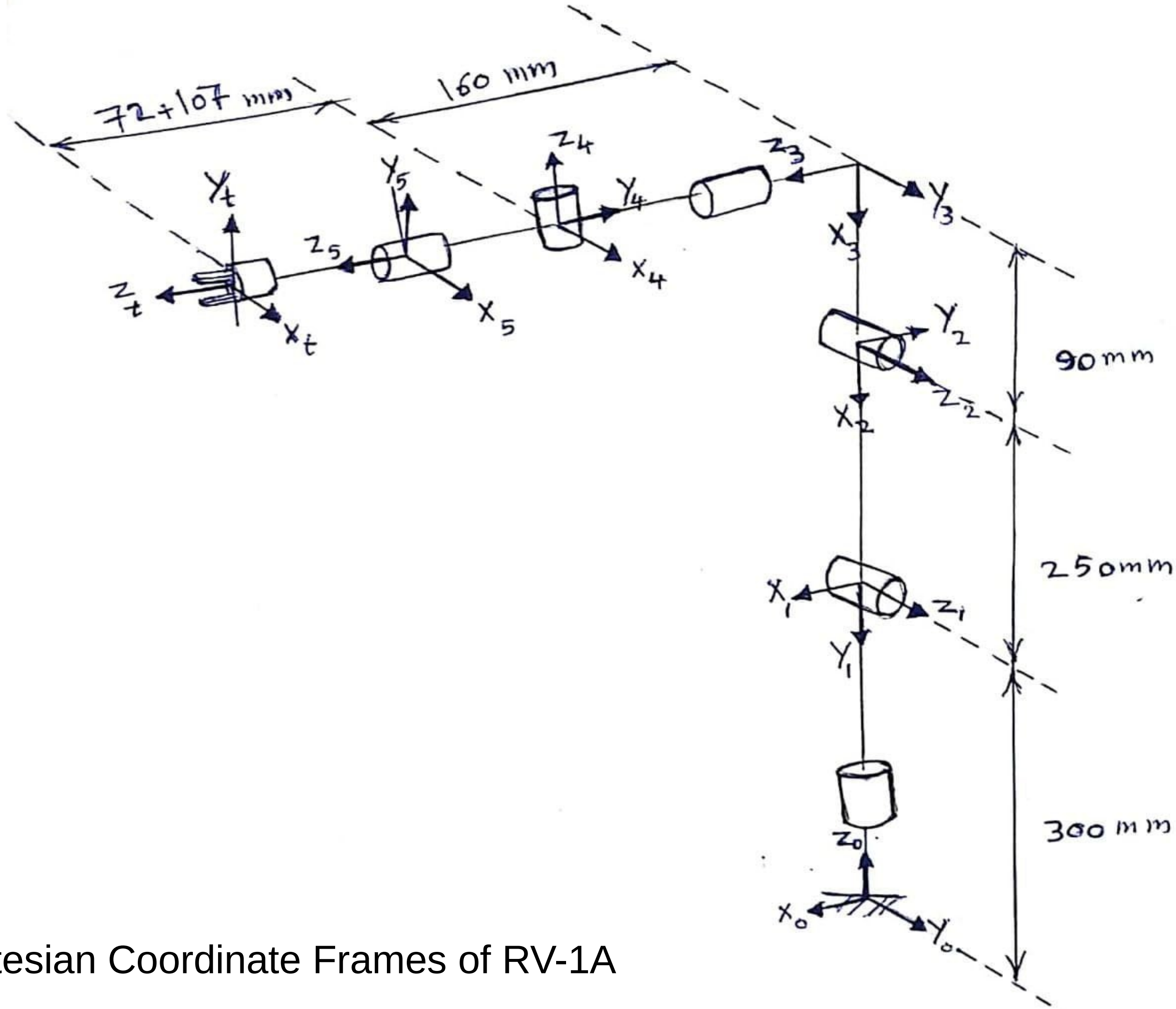
Mechanical Structure



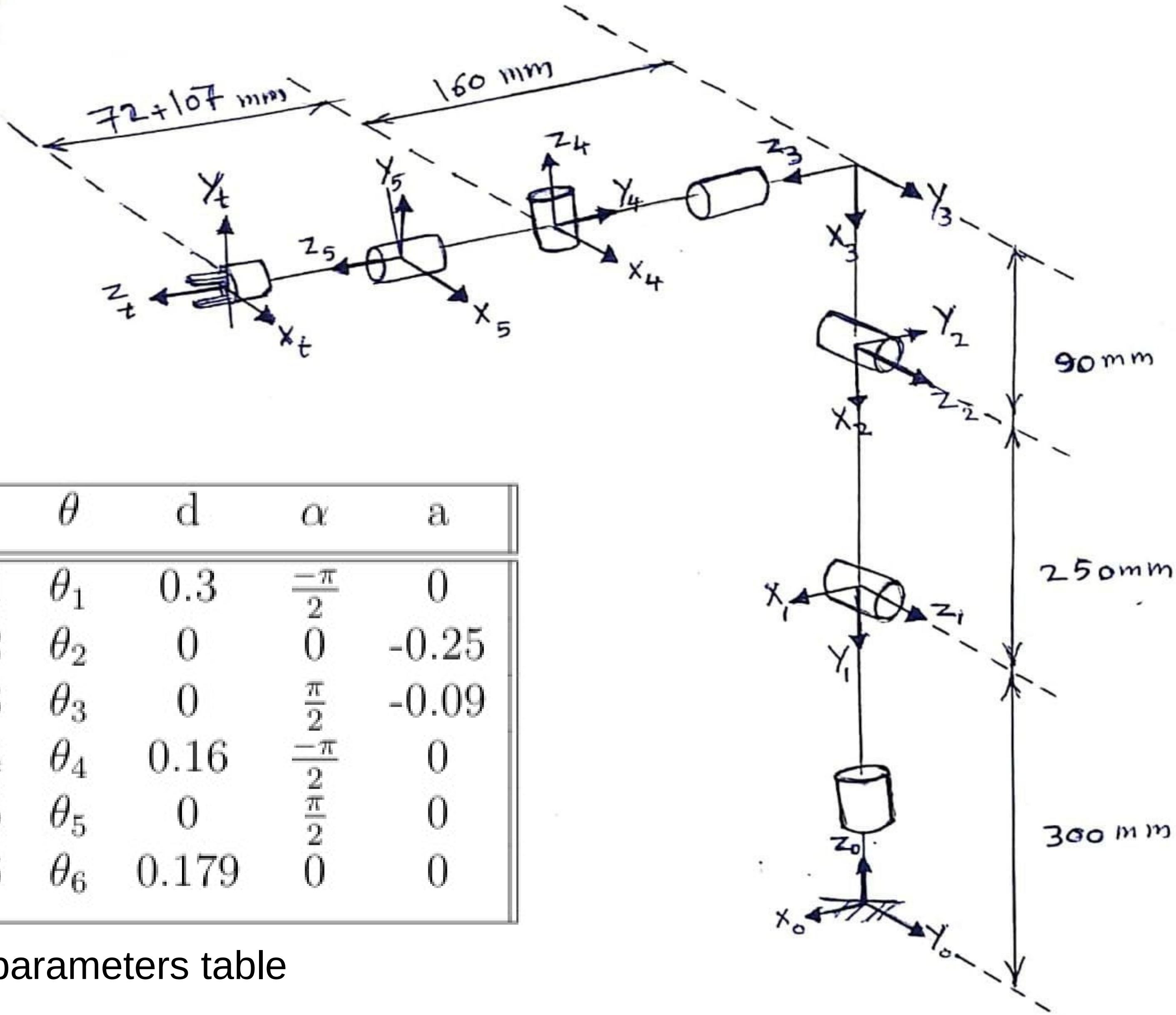
Mitsubishi RV-1A

Kinematic Analysis



Cartesian Coordinate Frames of RV-1A

Kinematic Analysis



i	θ	d	α	a
0-1	θ_1	0.3	$\frac{-\pi}{2}$	0
1-2	θ_2	0	0	-0.25
2-3	θ_3	0	$\frac{\pi}{2}$	-0.09
3-4	θ_4	0.16	$\frac{-\pi}{2}$	0
4-5	θ_5	0	$\frac{\pi}{2}$	0
5-6	θ_6	0.179	0	0

DH parameters table

Kinematic Analysis

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

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

Forward Kinematics

Kinematic Analysis

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

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

$$T_1^0(q_1)\mathbf{T_6^0} = T_2^1(q_2)....T_5^4\mathbf{T_6^5}$$

Inverse Kinematics (Paul Method)

Kinematic Analysis

$\cos(\theta) = a$	$\theta = a\tan 2(\pm\sqrt{1-a^2}, a)$	1
$\sin(\theta) = a$	$\theta = a\tan 2(a, \pm\sqrt{1-a^2})$	2
$\left.\begin{array}{l}\sin(\theta) = a \\ \cos(\theta) = b\end{array}\right\}$	$\theta = a\tan 2(a, b)$	3
$a\cos(\theta) - b\sin(\theta) = 0$	$\left\{\begin{array}{l}\theta = a\tan 2(a, b) \\ \theta = a\tan 2(-a, -b)\end{array}\right.$	4
$a.\cos(\theta) + b.\sin(\theta) = c$	$\theta = a\tan 2(c, \pm\sqrt{a^2 + b^2 - c^2}) - a\tan 2(a, b)$	5
$\left.\begin{array}{l}a.\cos(\theta) + b.\sin(\theta) = c \\ a.\cos(\theta) - b.\sin(\theta) = d\end{array}\right\}$	$\theta = a\tan 2(ac - ad, bc + bd)$	6

Inverse Kinematics (Paul Method)

Dynamic Analysis

$$M(q) + C(q, \dot{q})\dot{q} + g(q) = \tau$$

Euler-Lagrange Method (generalized Formula)

Dynamic Analysis

$$M(q) + C(q, \dot{q})\dot{q} + g(q) = \tau$$

Euler-Lagrange Method (generalized Formula)

Dynamic Analysis

$$M(q) + C(q, \dot{q})\dot{q} + g(q) = \tau$$

$$M(q) = \sum_{i=1}^{6} m_i \mathbb{J}_v^{i\,T} \mathbb{J}_v^i + \mathbb{J}_w^{i\,T} R_i I R_i^T \mathbb{J}_w^i$$

Euler-Lagrange Method (Math Matrix)

Dynamic Analysis

$$M(q) + C(q, \dot{q})\dot{q} + g(q) = \tau$$

$$C_{ij} = \sum_{k=1}^{6} c_{ijk}\dot{q}_k$$

Euler-Lagrange Method (Coriolis Matrix)

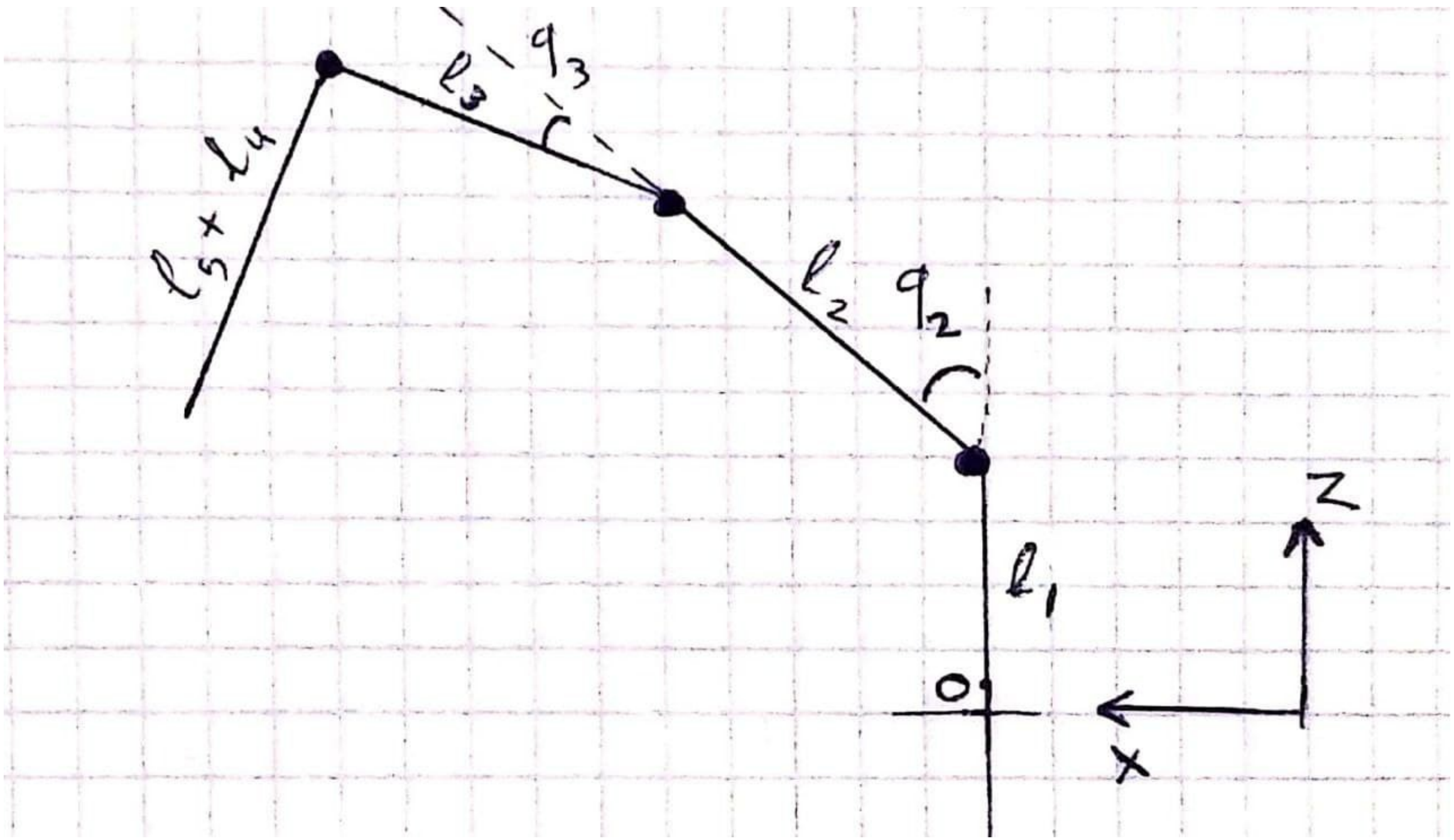
Dynamic Analysis

$$M(q) + C(q,\dot{q})\dot{q} + g(q) = \tau$$

$$g = \sum_{k=1}^{6} (\mathbb{J}_{wi}^{k})^T g_0$$

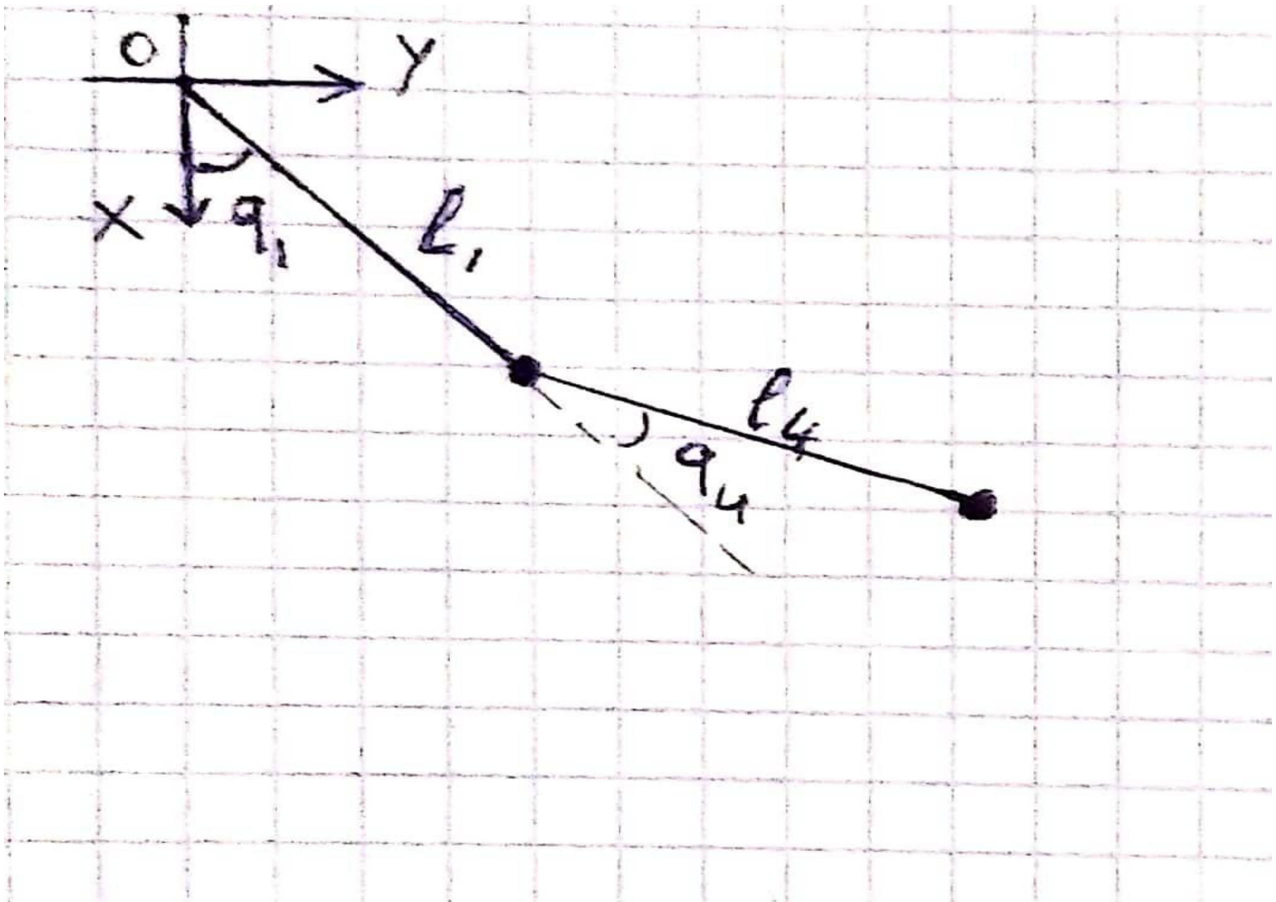
Euler-Lagrange Method (Gravity Matrix)

Dynamic Analysis



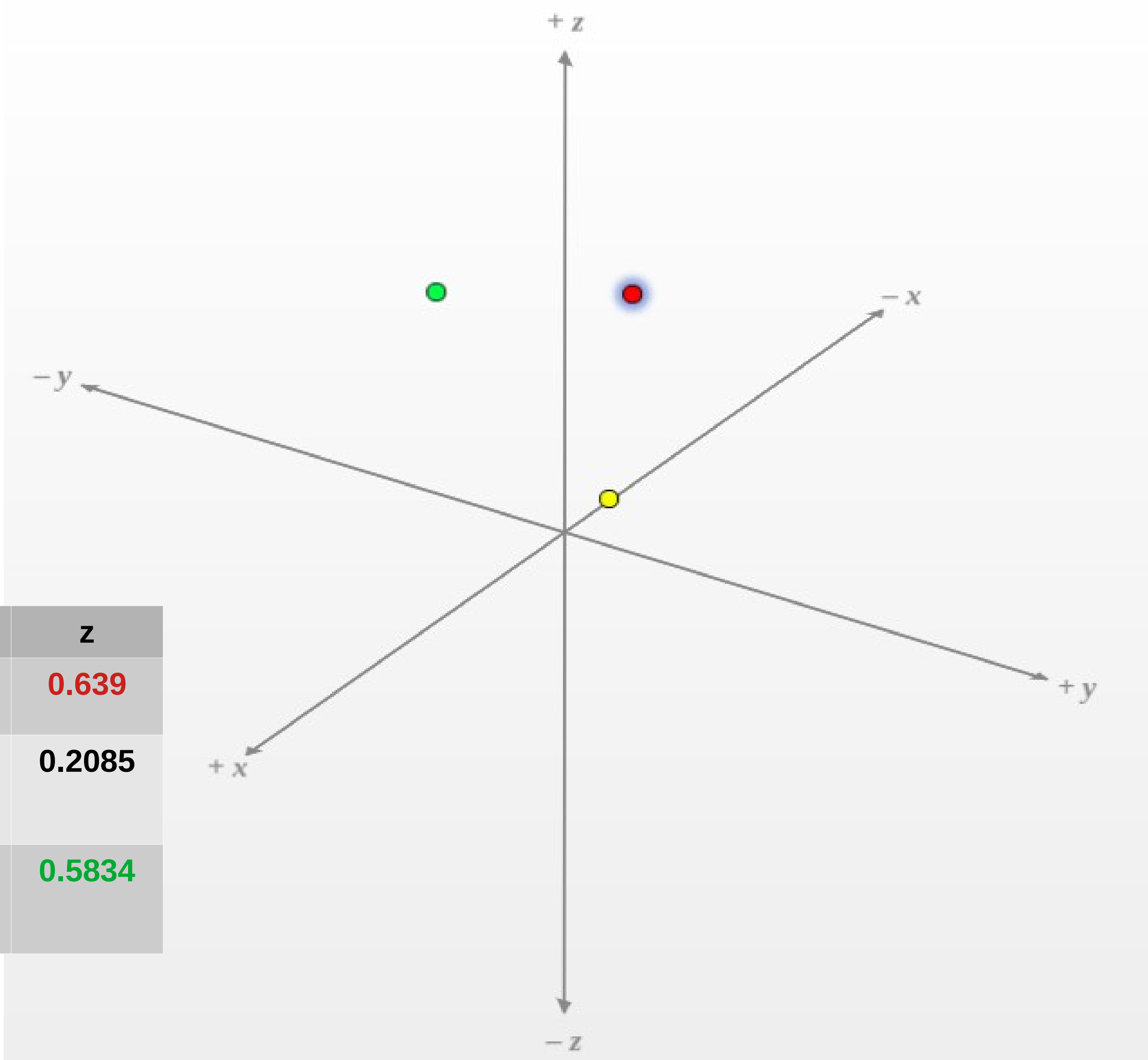
Euler-Lagrange Method (side view of RV-1A)

Dynamic Analysis



Euler-Lagrange Method (Top view of RV-1A)

Implementation



	x	y	z
Point 1	-0.3400	0	0.639
Point 2	0.0753	0.1964	0.2085
Point 3	-0.1337	-0.5156	0.5834

Task (Cartesian space)

Implementation

Q1	Q2	Q3
0	-5.7853	7.5921
0	3.7521	0.5532
0	2.4453	11.1868
0	1.2217	3.4214
0	2.1942	0.0872
0	1.7433	5.7279

IK

	x	y	z
Point 1	-0.3400	0	0.639
Point 2	0.0753	0.1964	0.2085
Point 3	-0.1337	-0.5156	0.5834

Task (Joint space) ps: the orientation is not displayed here

Implementation

	q1	q2	q3	q4	q5	q6
Max velocity [rad/sec]	3.14159	1.5708	2.35619	3.14159	3.14159	3.66519
Max Acceleration [rad/(s^2)]	12	8	10	4	4	2

Trajectory Planning (defining the inputs)

Implementation

Q1	Q2	Q3
0	-5.7853	7.5921
0	3.7521	0.5532
0	2.4453	11.1868
0	1.2217	3.4214
0	2.1942	0.087
0	1.7433	5.7279

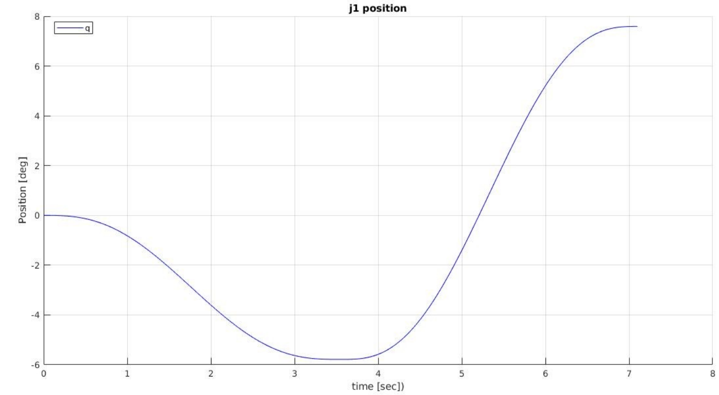
Trajectory Planning (defining the inputs)

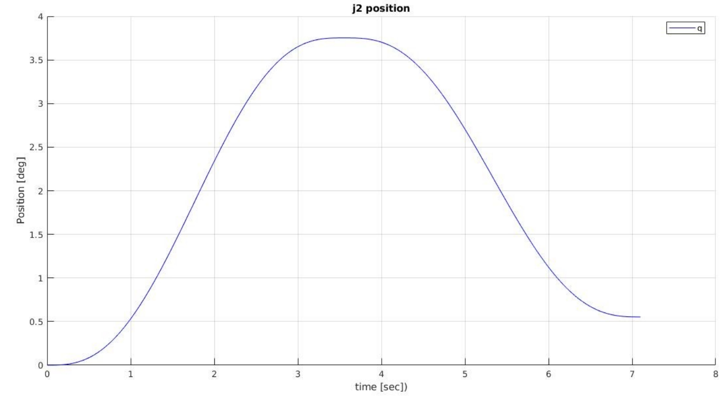
Implementation

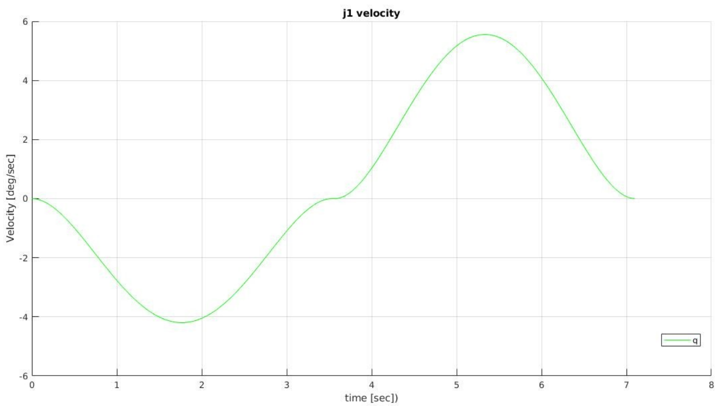
$$A = \begin{bmatrix} 1 & t_0 & t_0^2 & t_0^3 & t_0^4 & t_0^5 \\ 0 & 1 & 2t_0 & 3t_0^2 & 4t_0^3 & 5t_0^4 \\ 0 & 0 & 2 & 6t_0 & 12t_0^2 & 20t_0^3 \\ 1 & t_f & t_f^2 & t_f^3 & t_f^4 & t_f^5 \\ 0 & 1 & 2t_f & 3t_f^2 & 4t_f^3 & 5t_f^4 \\ 0 & 0 & 2 & 6t_f & 12t_f^2 & 20t_f^3 \end{bmatrix} \qquad B = \begin{bmatrix} q_{i0} \\ \dot{q}_{i0} \\ \ddot{q}_{i0} \\ q_{if} \\ \dot{q}_{if} \\ \ddot{q}_{if} \end{bmatrix}$$

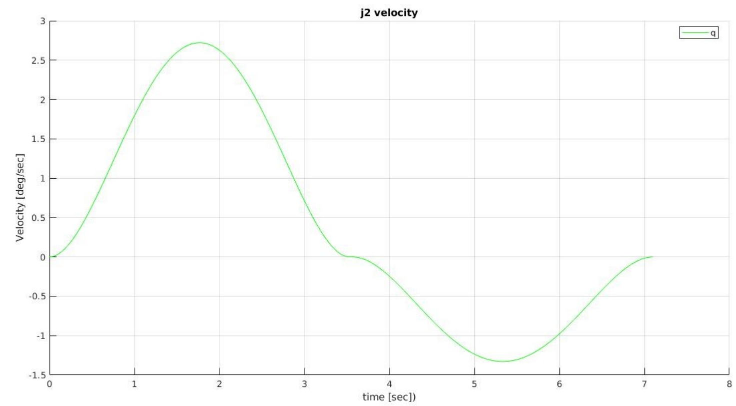
Ax=B

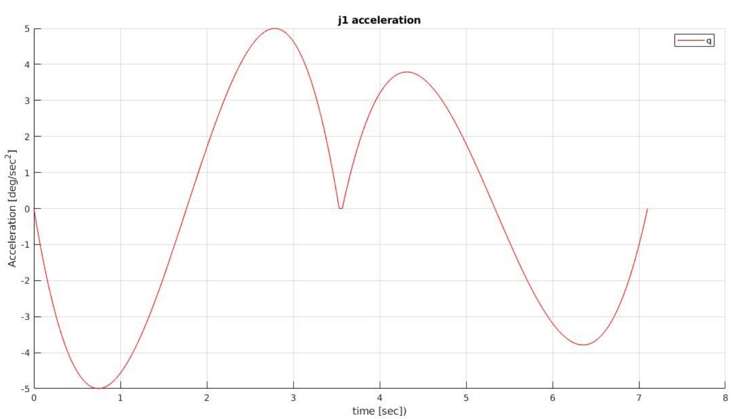
Trajectory Planning (Polynomial method)

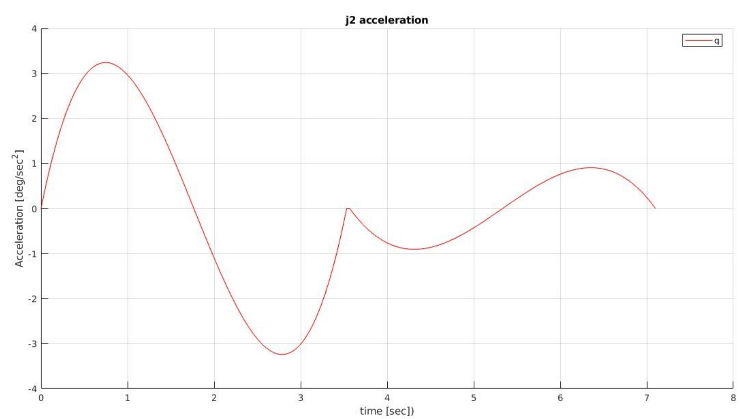




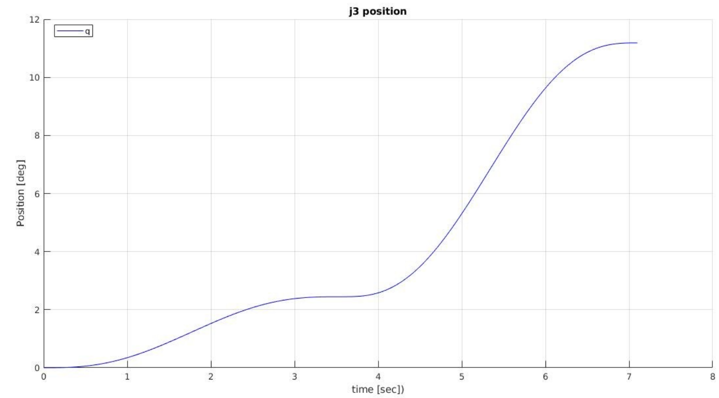


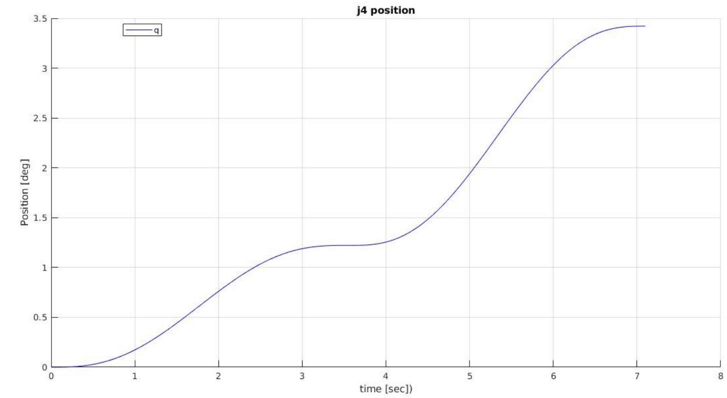


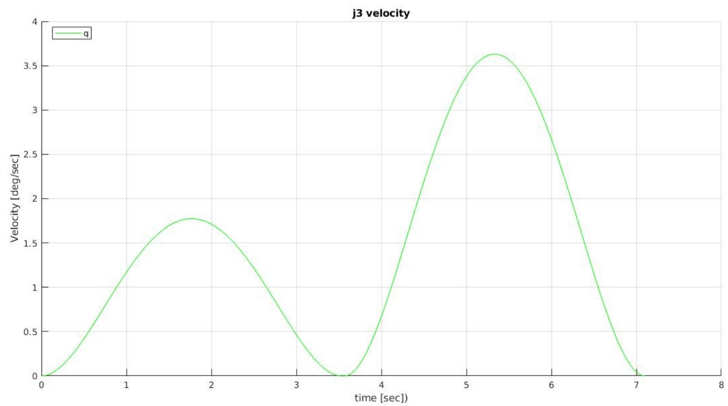


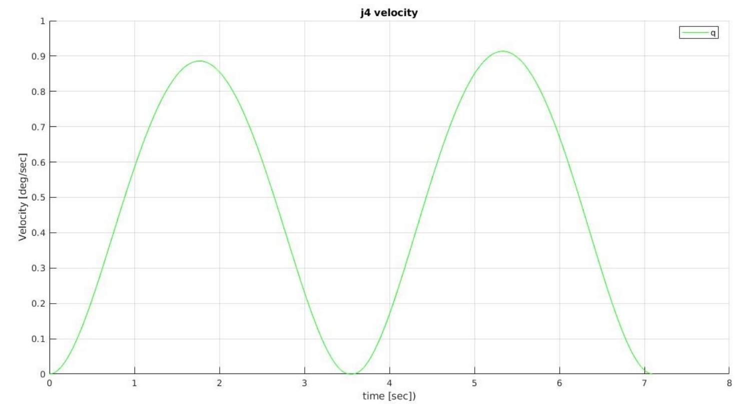


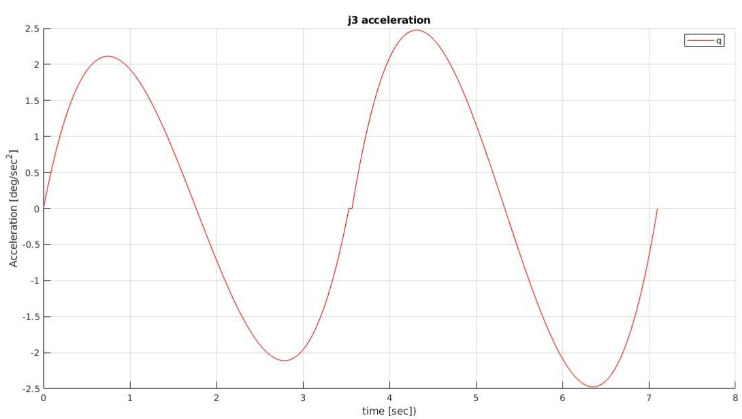
Trajectory Planning (results)

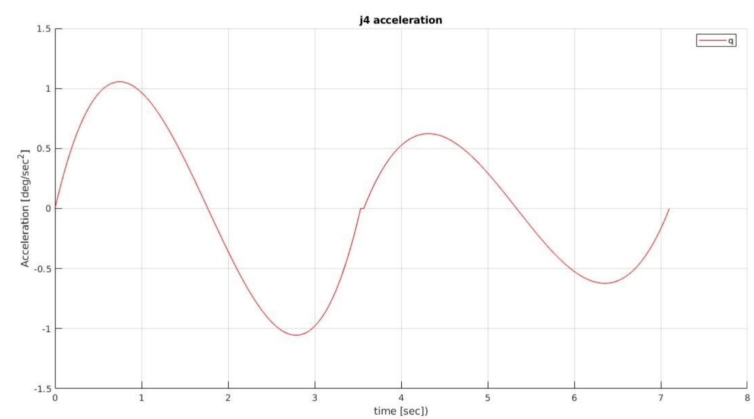




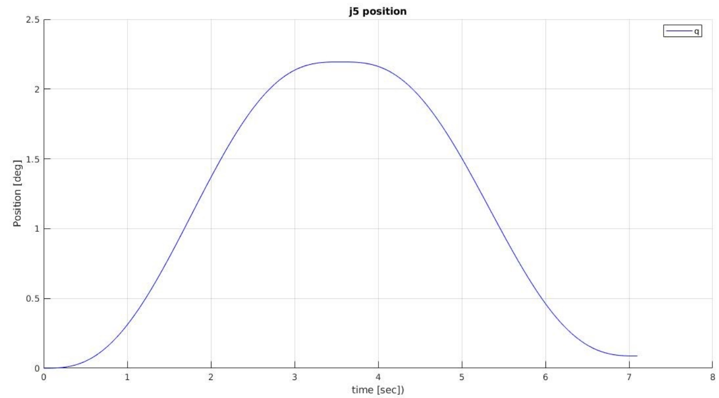


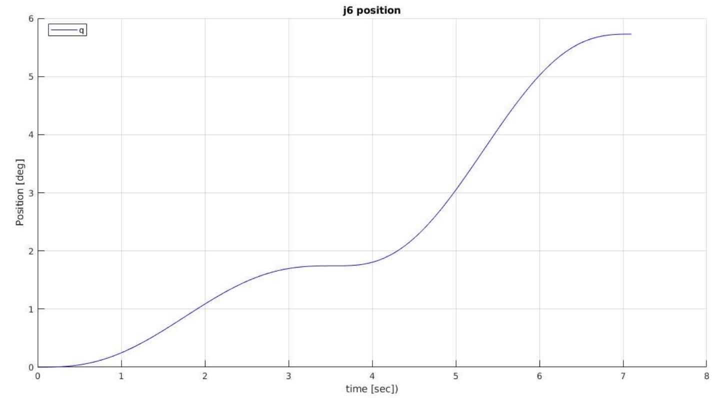


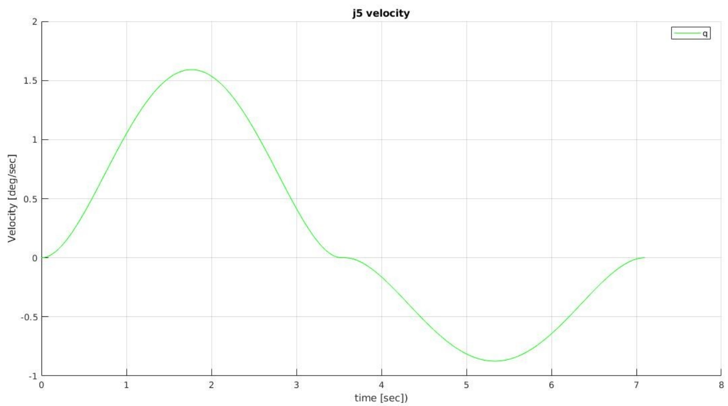


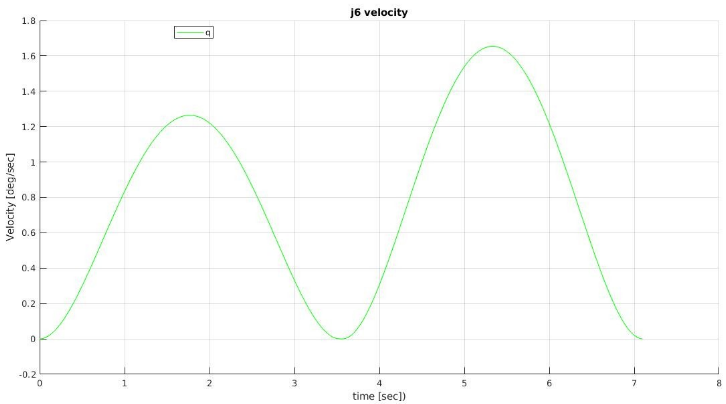


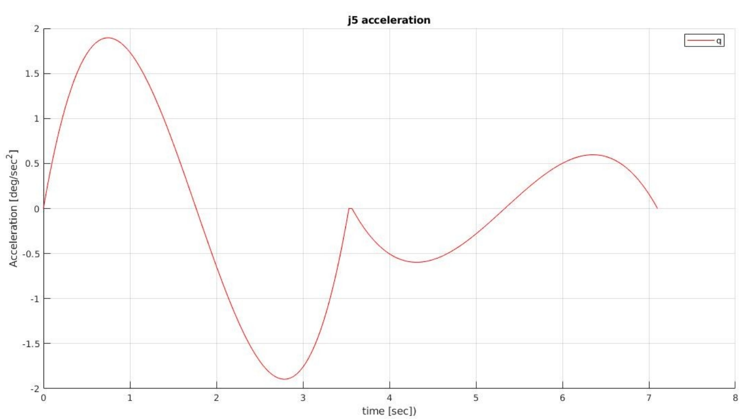
Trajectory Planning (results)

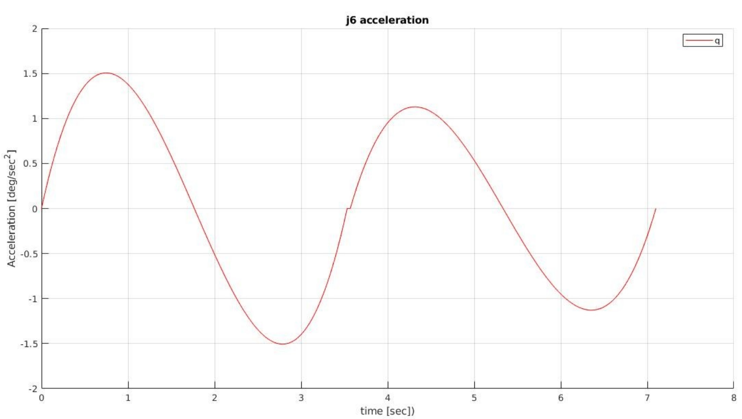












Trajectory Planning (results)

Thank You