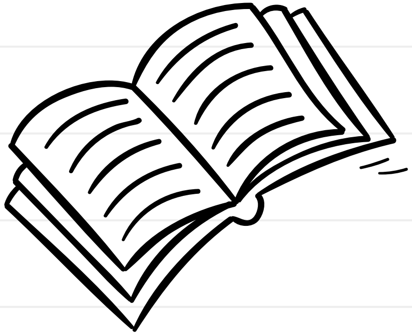
MTAB ARISTO ROBOT KINEMATIC ANALYSIS SIMULATION

ALL ABOUT PROJECT

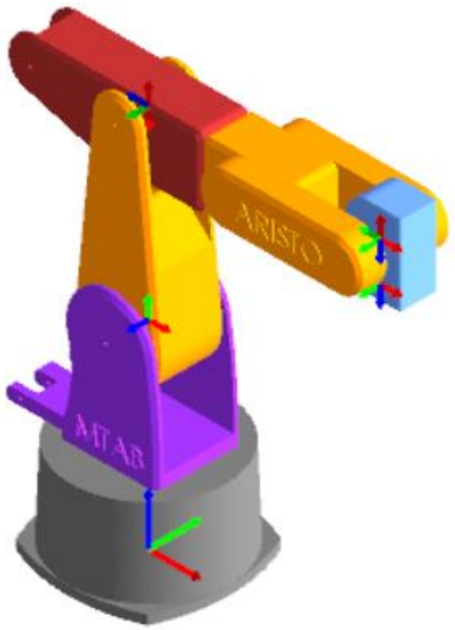
- INTRODUCTION
- ALGORITHMS
- CONCLUSION
- CODE
- CONCLUSION

Introduction

OBJECTIVE : To Apply Forward and Inverse Kinematics to MTAB Aristo

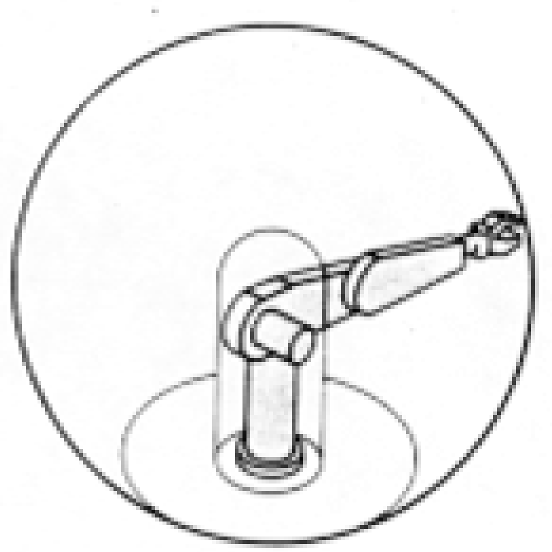


MTAB Aristo Model



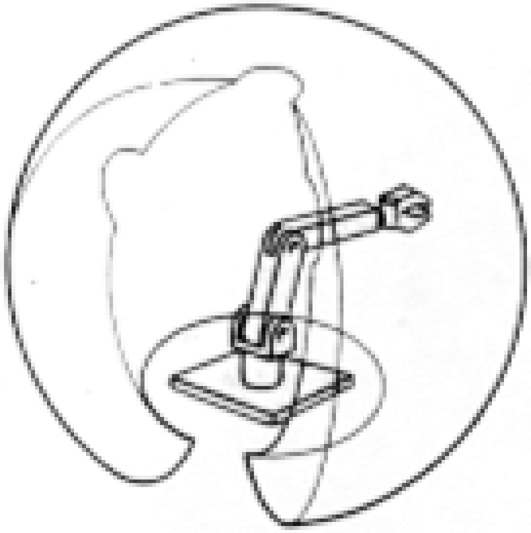
Work envelope

The range of the movement of the End Effector

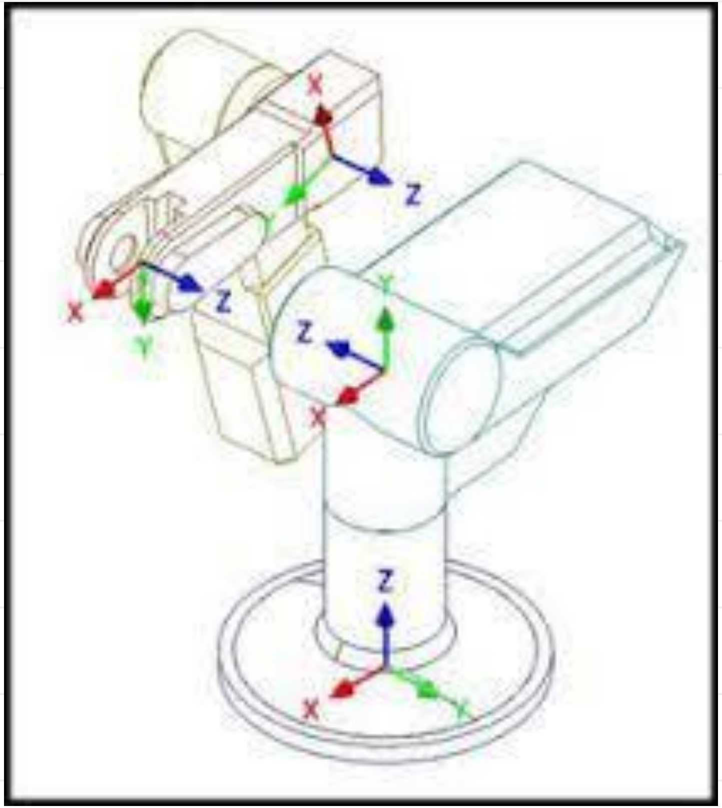


Work volume

The volume inside which robot can position the end effector.



DH PARAMETERS



$$\begin{array}{cccc} \alpha_i & a_i & d_i & \theta_i \end{array}$$
$$\begin{bmatrix} 90 & 0 & 0.322 & \theta_1 \\ 0 & 0.3 & 0 & \theta_2 \\ 90 & 0 & 0 & \theta_3 \\ 90 & 0 & -0.375 & \theta_4 \\ 90 & 0 & 0 & \theta_5 \\ 0 & 0 & 0.063 & \theta_6 \end{bmatrix}$$

FORWARD KINEMATICS

Compute the position of the end-effector from specified values for the joint parameters

01 Assigning the Axes

a. Z is always assigned along which joint motion occurs.

b. X along the shortest common normal Between Z axes

c. Y Completes the Right Hand System

02

Calculating the DH Parameters

A

$\alpha_{(i-1)}$ - rotation angle about $X_{(i-1)}$ from $Z_{(i-1)}$ to $Z_{(i)}$

B

$a_{(i-1)}$ - Translation about $X_{(i-1)}$

C

$\theta_{(i)}$ - rotation about Z_i aligned along X_{i-1} and X_i

D

D_i - Translation about Z_i

03

Calculating the DH Parameters

$$
{}^{i-1}T_i = \begin{bmatrix} \cos\theta_i & -\sin\theta_i \cos\alpha_{i,i+1} & \sin\theta_i \sin\alpha_{i,i+1} & a_{i,i+1}\cos\theta_i \\ \sin\theta_i & \cos\theta_i \cos\alpha_{i,i+1} & -\cos\theta_i \sin\alpha_{i,i+1} & a_{i,i+1}\sin\theta_i \\ 0 & \sin\alpha_{i,i+1} & \cos\alpha_{i,i+1} & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix},
$$

04

Multiplying all the Transformation Matrix to get the Final Transformation Matrix

05

Multiplying with Base Coordinates

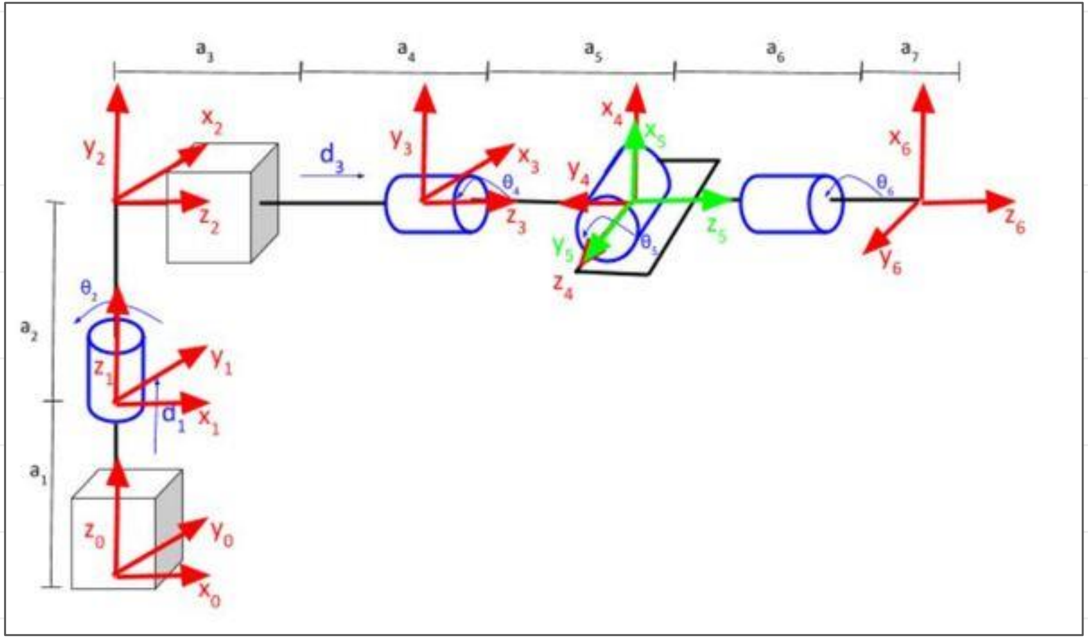
06

The obtained Matrix is the End effector Coordinates.

INVERSE KINEMATICS

01

GIVEN THE END EFFECTOR COORDINATES
WE NEED TO FIND THE JOINT COORDINATES

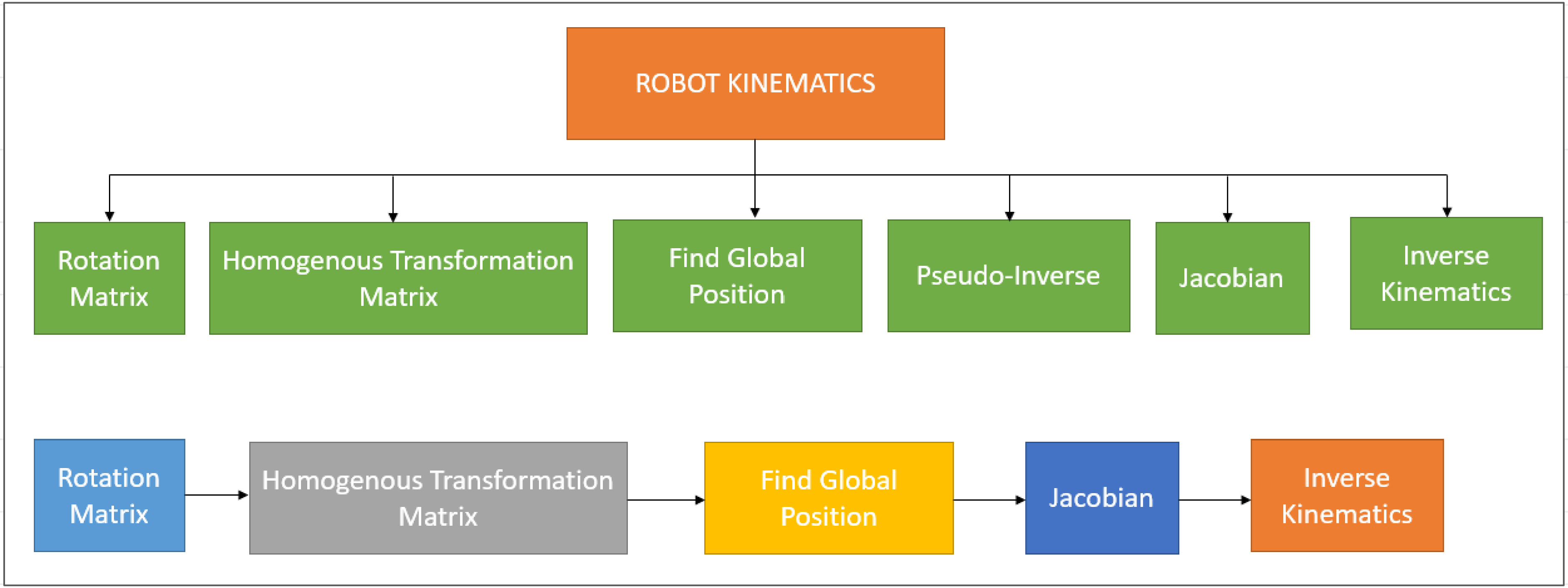


APPROACHES TO SOLVE THIS IK PROBLEM

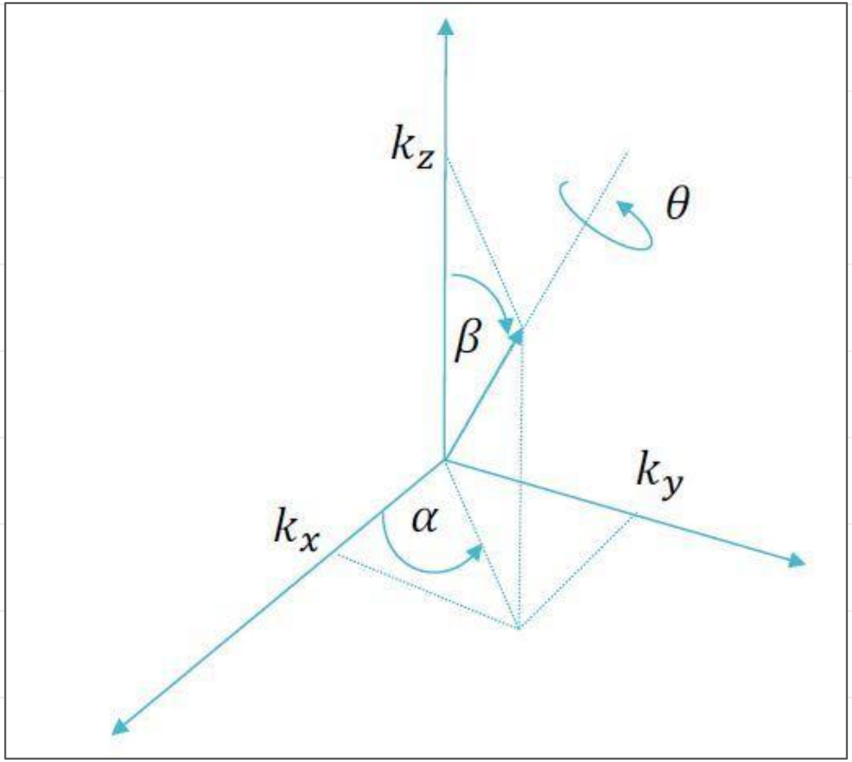
Analytical approach

Numerical approach

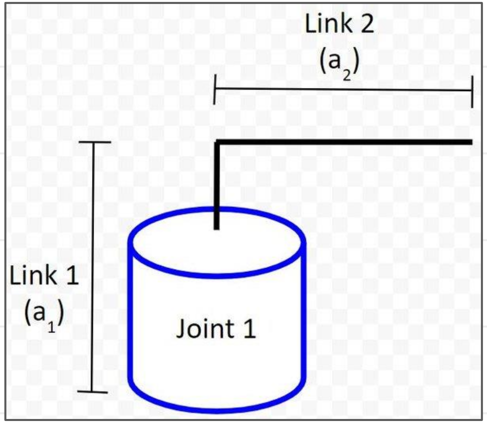
OVERVIEW OF INVERSE KINEMATICS IMPLEMENTATION

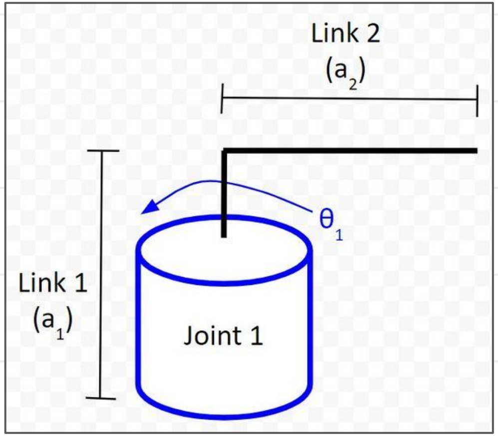


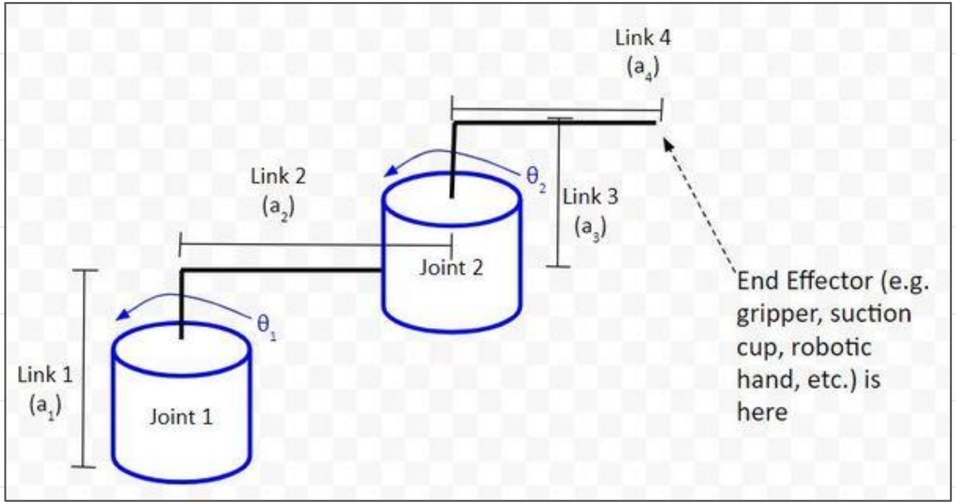
٥١ AXIS ANGLE ROTATION REPRESENTATION



$$\text{Axis: } k = \begin{pmatrix} k_x \\ k_y \\ k_z \end{pmatrix} \quad \text{Angle: } \theta$$


Link 2
(a2)
Link 1
(a1)
Joint 1


Link 2
(a2)
θ1
Link 1
(a1)
Joint 1


Link 4
(a4)
Link 2
(a2)
θ2
Link 3
(a3)
Joint 2
θ1
Link 1
(a1)
Joint 1
End Effector (e.g. gripper, suction cup, robotic hand, etc.) is here

Equivalent 3x3 rotation matrix:

$$R_k(\theta) = \begin{bmatrix} k_x k_x(1-\cos\theta)+\cos\theta & k_x k_y(1-\cos\theta)-k_z\sin\theta & k_x k_z(1-\cos\theta)+k_y\sin\theta \\ k_x k_y(1-\cos\theta)+k_z\sin\theta & k_y k_y(1-\cos\theta)+\cos\theta & k_y k_z(1-\cos\theta)-k_x\sin\theta \\ k_x k_z(1-\cos\theta)-k_y\sin\theta & k_y k_z(1-\cos\theta)+k_x\sin\theta & k_z k_z(1-\cos\theta)+\cos\theta \end{bmatrix}$$

02 HOMOGENEOUS TRANSFORMATION MATRIX

homgen_n-1_n =

$$\left[\begin{array}{ccc|c} \cos\theta_n & -\sin\theta_n\cos\alpha_n & \sin\theta_n\sin\alpha_n & r_n\cos\theta_n \\ \sin\theta_n & \cos\theta_n\cos\alpha_n & -\cos\theta_n\sin\alpha_n & r_n\sin\theta_n \\ 0 & \sin\alpha_n & \cos\alpha_n & d_n \\ \hline 0 & 0 & 0 & 1 \end{array}\right] = \left[\begin{array}{ccc|c} & R & & T \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

03 POSITION METHOD

TO FIND THE GLOBAL POSITION WITH RESPECT TO THE LOCAL COORDINATES

04 PSEUDO-INVERSE METHOD

COMPUTES THE PSEUDO-INVERSE OF THE JACOBIAN

05 JACOBIAN METHOD

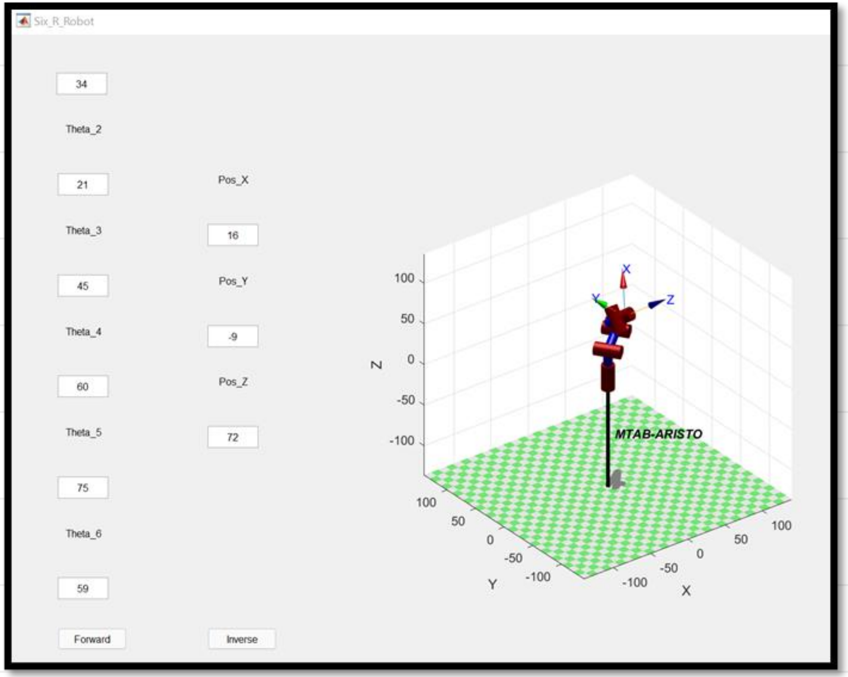
COMPUTES THE JACOBIAN MATRIX

$$J = \begin{bmatrix} J_v \\ J_w \end{bmatrix} = \begin{bmatrix} R^0_{i-1} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \times (d^0_n - d^0_{i-1}) \\ R^0_{i-1} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \end{bmatrix}$$

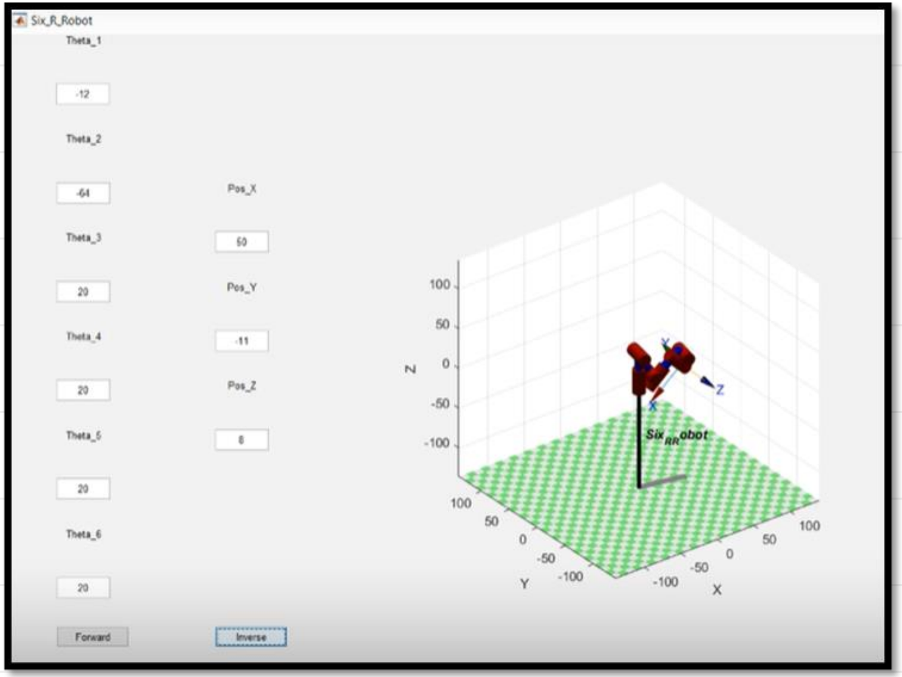
MAIN() METHOD

INPUT - TARGET POSITION
OUTPUT - JOINT VARIABLES

ROBOT SIMULATION - MATLAB



FORWARD KINEMATICS



INVERSE KINEMATICS

JACOBIAN

HELPS TO CONVERT JOINT VELOCITIES TO END-EFFECTOR VELOCITY

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \\ \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}_{6\times 1} = \begin{bmatrix} \square & \square & \square \\ \square & \square & \square \\ \square & \square & \square \\ \square & \square & \square \\ \square & \square & \square \\ \square & \square & \square \end{bmatrix} \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \end{bmatrix}_{3\times 1}$$

$$J = \begin{bmatrix} J_v \\ J_\omega \end{bmatrix}_{6\times n}$$

GENERAL FORM OF THE JACOBIAN

$$J = \begin{bmatrix} J_v \\ J_w \end{bmatrix} = \begin{bmatrix} R_{i-1}^0 \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \times (d_n^0 - d_{i-1}^0) \\ R_{i-1}^0 \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \end{bmatrix}$$

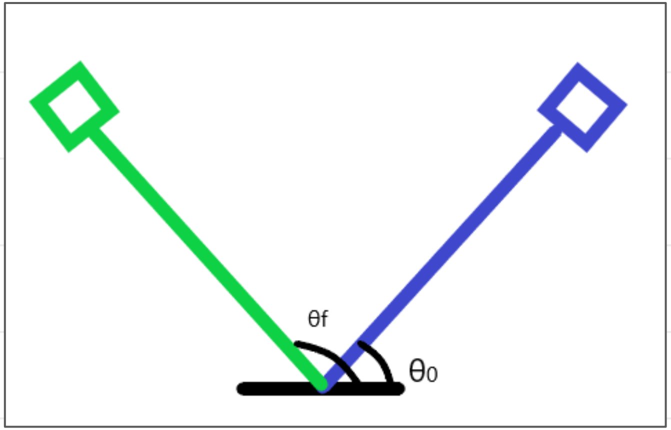
TRAJECTORY PLANNING

TRAJECTORY - TIME EVOLUTION OF POSITION, VELOCITY & ACCELERATION

01

START WITH 1 LINK MANIPULATOR

CONSIDER 1 DEGREE POLYNOMIAL



CONSIDER A 3 DEGREE POLYNOMIAL

$$\theta = a_0 + a_1 t + a_2 t^2 + a_3 t^3 \quad \rightarrow (1)$$

$$\dot{\theta} = a_1 + 2a_2 t + 3a_3 t^2 \quad \rightarrow (2)$$

$$\ddot{\theta} = 2a_2 + 6a_3 t \quad \rightarrow (3)$$

INITIAL POSITION & FINAL POSITION

From(1)

$$\theta(0) = \theta_0 \quad \Rightarrow \boxed{\theta_0 = a_0}$$

$$\theta(t_f) = \theta_0 \quad \Rightarrow \theta_f = \theta_0 + a_1 t_f + a_2 t_f^2 + a_3 t_f^3$$

INITIAL VELOCITY & FINAL VELOCITY

From(2)

$$\dot{\theta}(0) = 0 \quad \Rightarrow \boxed{a_1 = 0}$$

$$\dot{\theta}(t_f) = 0 \quad \Rightarrow 2a_2 t_f + 3a_3 t_f^2 = 0$$

$$a_2 t_f^2 + a_3 t_f^3 = \theta_f - 0 \quad \rightarrow (4)$$

$$2a_2 t_f + 3a_3 t_f^2 = 0 \quad \rightarrow (5)$$

$$\begin{bmatrix} t_f^2 & t_f^3 \\ 2t_f & 3t_f^2 \end{bmatrix} \begin{bmatrix} a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} \theta_f - \theta_0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} t_f^2 & t_f^3 \\ 0 & t_f^2 \end{bmatrix} \begin{bmatrix} a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} \theta_f - \theta_0 \\ \dfrac{-2(\theta_f - \theta_0)}{t_f} \end{bmatrix}$$

$$\boxed{a_3 = \frac{-2(\theta_f - \theta_0)}{t_f^3}}$$

$$t_f^2 a_2 + a_3 t_f^3 = \theta_f - \theta_0$$

$$t_f^2 a_2 - 2(\theta_f - \theta_0) = \theta_f - \theta_0$$

$$\boxed{a_2 = \frac{3(\theta_f - \theta_0)}{t_f^2}}$$

Substitute a0, a1, a2 and a3 in the polynomial equations to get equations for angular displacement, angular velocity, angular acceleration

CODE

ROBO-ANALYZER

01

Loading the Mtab aristo Model in Roboanalyzer.

02

Visualizing the DH Parameters of Each Joint.

FORWARD KINEMATICS

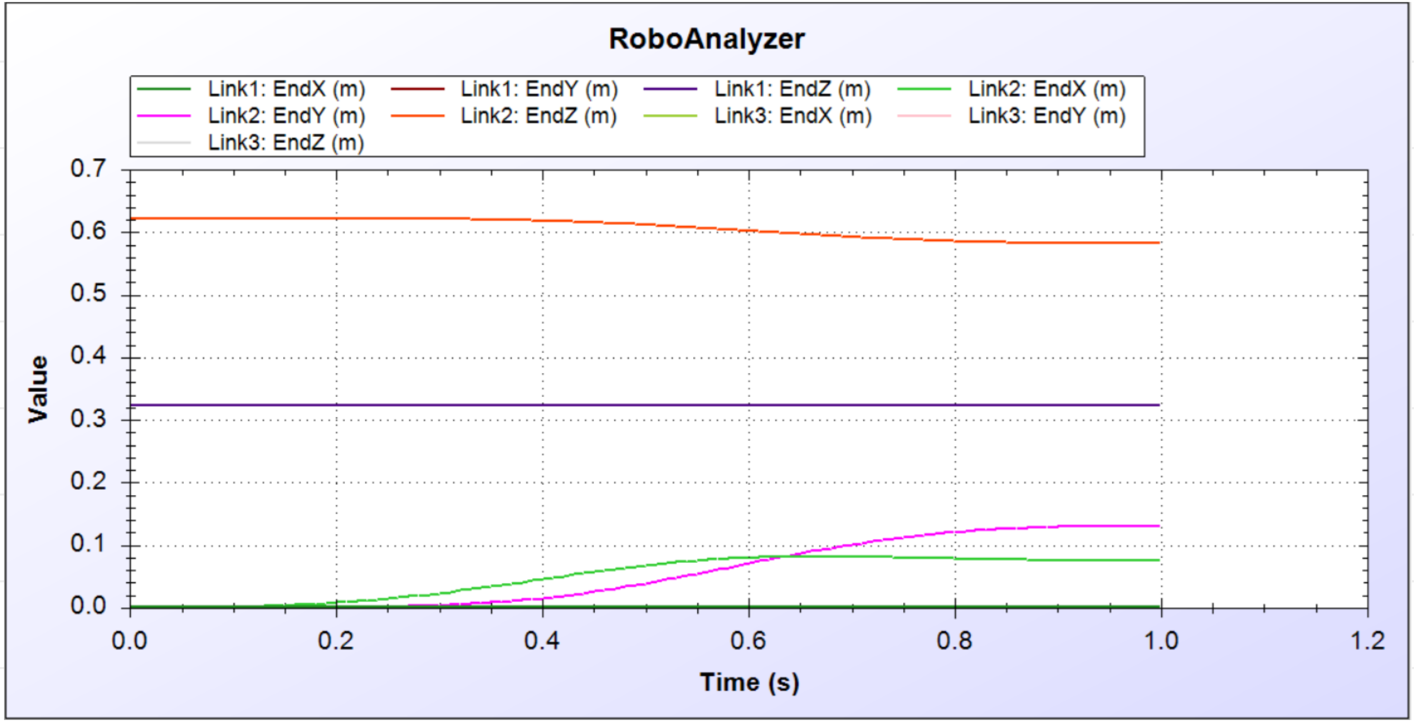
01 Initializing the Value of Initial degree and Final degree for each joint.

02 Obtaining Link Configuration of Each Link wrt Base Frame

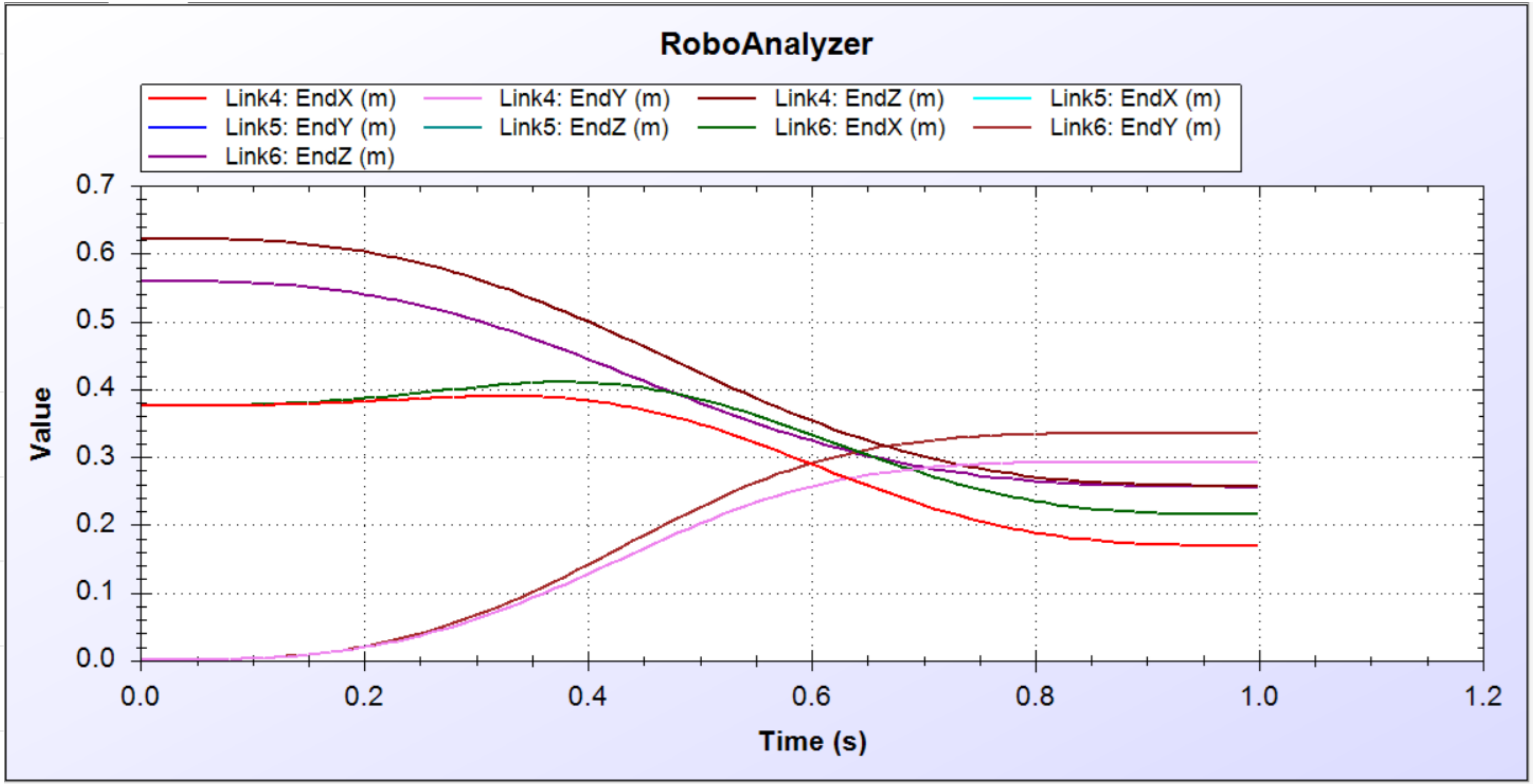
03 Applying Forward Kinematics analysis to the Model.

04 Plotting the Graph for Forward Kinematics.

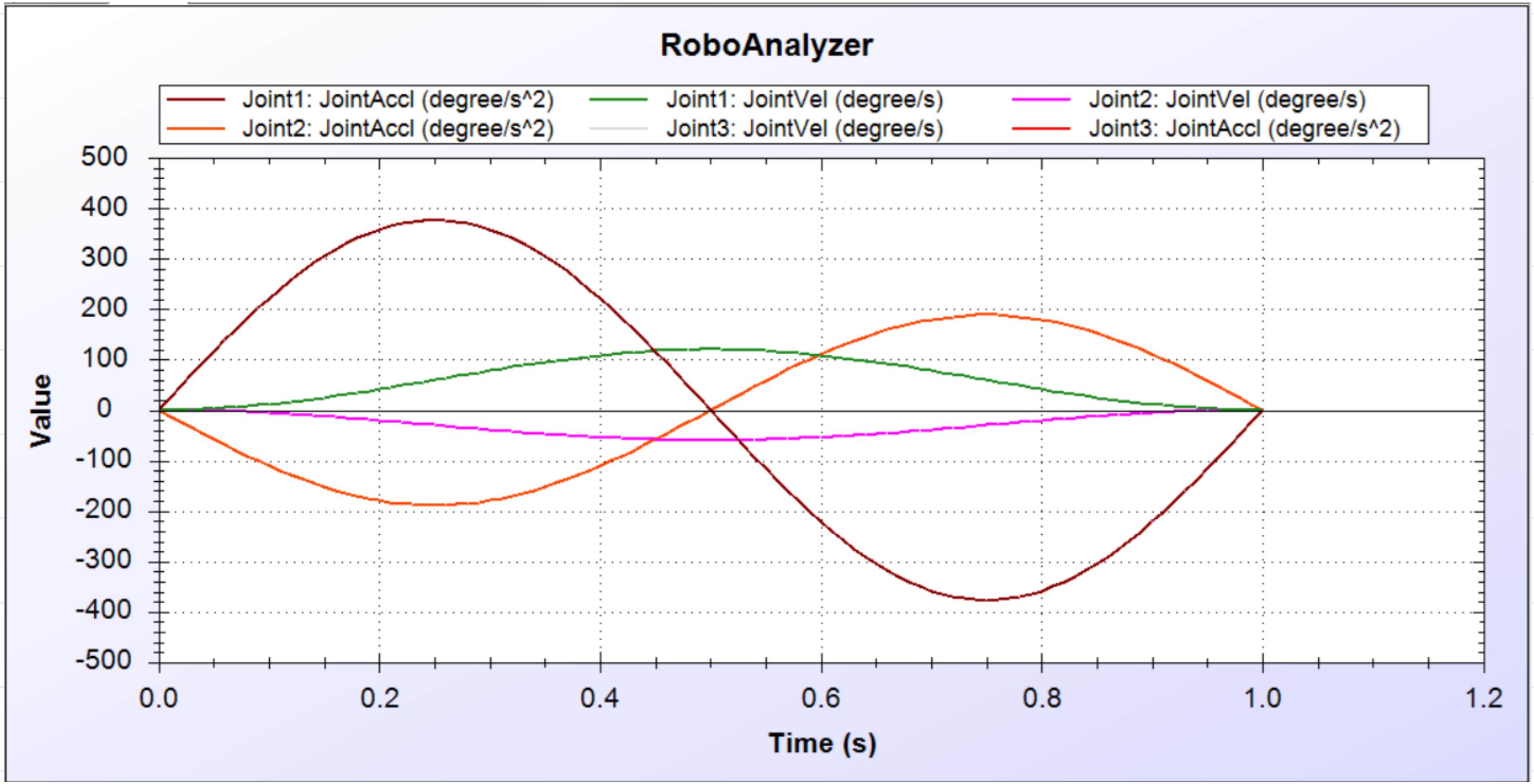
Link 1, 2, 3 plot



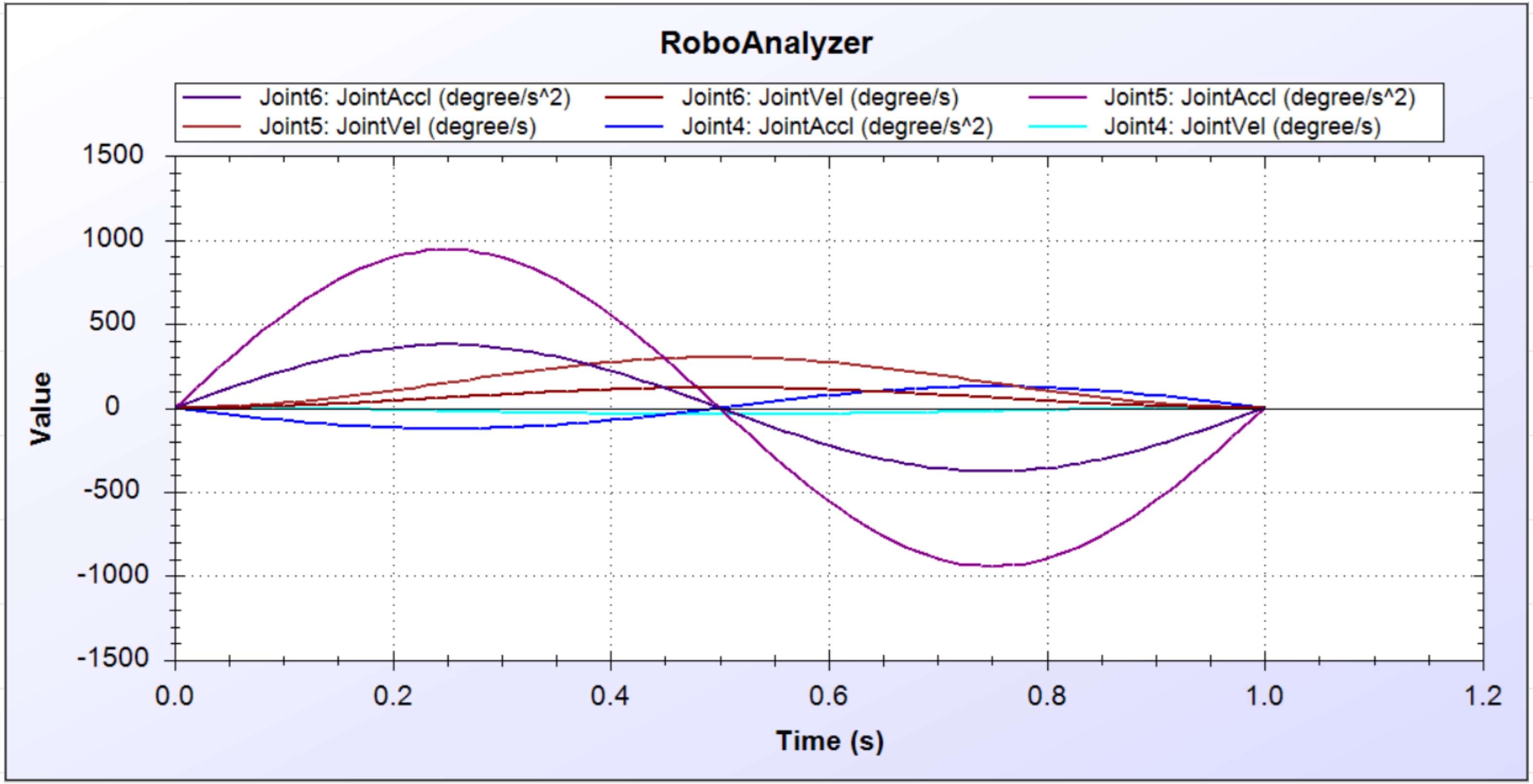
LINK 4, 5, 6 PLOT



Joints 1, 2, 3 – Velocity, Acceleration Graphs:



Joints 4, 5, 6 – Velocity, Acceleration Graphs:



Inverse Kinematics

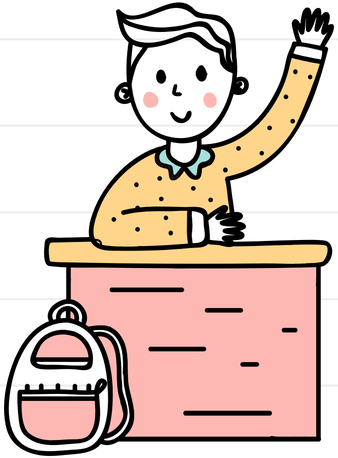
01 Initializing the Joint Offset,Link Length, Twist Angle for 6 links and 6 joints respectively

02 Initializing the End Effector Position And Orientation Matrix

03 Computing 8 Initial Position Solution Using Inverse Kinematics Analysis.

04 Using “show” we could view the solution in the 3D model

05 We could use these solutions to set the Initial and Final value of Joints for Forward Kinematics computation.



THANK YOU