Foundations of Robotics: Project-2

Name: Shubham Gupta
Netid: sg7761

Fall 22

1 Objective

Implement second order kinematics and relax Z component from a sphere for a given SCARA manipulator

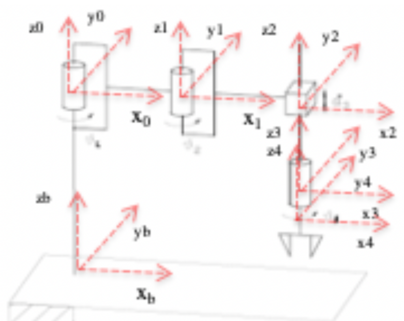


Figure 1: DH diagram for SCARA manipulator.

2 Part-1

Implemented second order kinematic inversion using Matlab and Simulink for the given trajectory using jacobian inverse

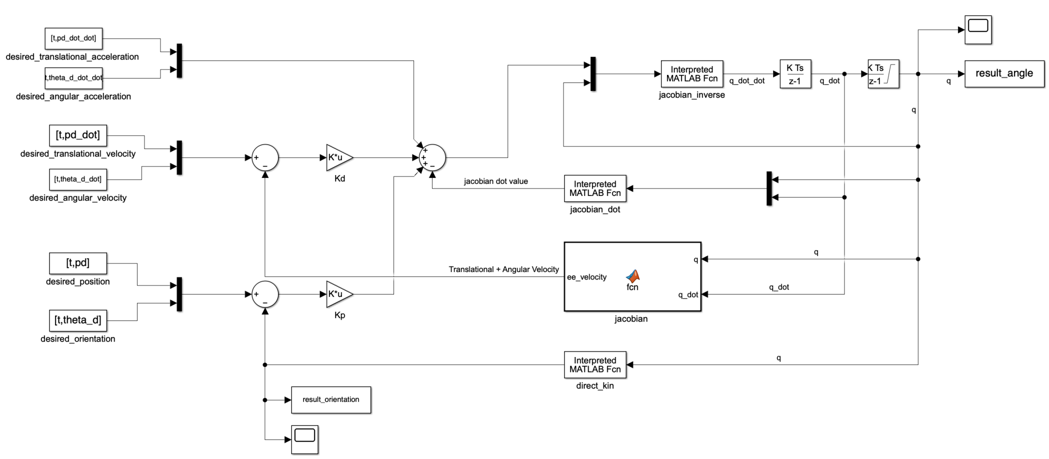


Figure 2: Simulink block diagram for second order inverse kinematics using Jacobian inverse.

The model uses interpreted matlab blocks to use the existing M files defined in the project structure. The model uses a gain value of 75 in an identity matrix to reach its optimum solution.

$$jacobian\_matrix = \begin{bmatrix} -a_2 \sin(\theta_1+\theta_2) - a_1 \sin(\theta_1) & -a_2 \sin(\theta_1+\theta_2) & 0 & 0 \\ a_2 \cos(\theta_1+\theta_2) + a_1 \cos(\theta_1) & a_2 \cos(\theta_1+\theta_2) & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 1 & 0 & 1 \end{bmatrix} \tag{1}$$

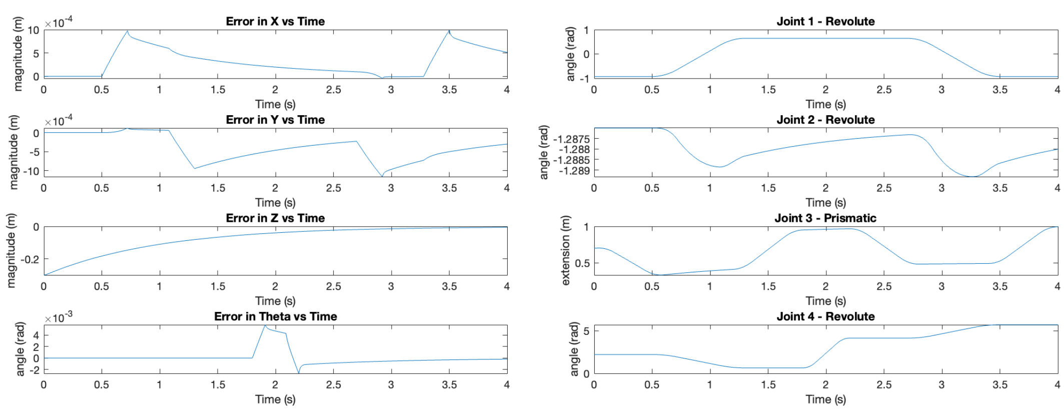
$$q\_dot = inv(jacobian\_matrix) \cdot Ke \tag{2}$$

$$jacobian\_dot\_pre = \begin{bmatrix} -a_2 \cos(\theta_1+\theta_2) * (\theta_1+\theta_2) - a_1 \cos(\theta_1) * \theta_1 & -a_2 \cos(\theta_1+\theta_2) * (\theta_1+\theta_2) & 0 & 0 \\ -a_2 \sin(\theta_1+\theta_2) * (\theta_1+\theta_2) - a_1 \sin(\theta_1) * (\theta_1) & -a_2 \sin(\theta_1+\theta_2) * (\theta_1+\theta_2) & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \tag{3}$$

$$jacobian\_dot = jacobian\_dot\_pre \cdot q\_dot \tag{4}$$

$$HT\_matrix = \begin{bmatrix} \cos(\theta_1+\theta_2+\theta_4) & -\sin(\theta_1+\theta_2+\theta_4) & 0 & a_2 \cos(\theta_1+\theta_2) + a_1 \cos(\theta_1) \\ \sin(\theta_1+\theta_2+\theta_4) & \cos(\theta_1+\theta_2+\theta_4) & 0 & a_2 \sin(\theta_1+\theta_2) + a_1 \sin(\theta_1) \\ 0 & 0 & 1 & base - d3 \end{bmatrix} \tag{5}$$

Graphs



(a) (b)

Figure 3: Graphs generated for inverse kinematics of SCARA using Jacobian Inverse.**(a)**Error in Operational space of X, Y, Z and Theta across time. **(b)**Value of joint angles / extension across time.

3 Part-2

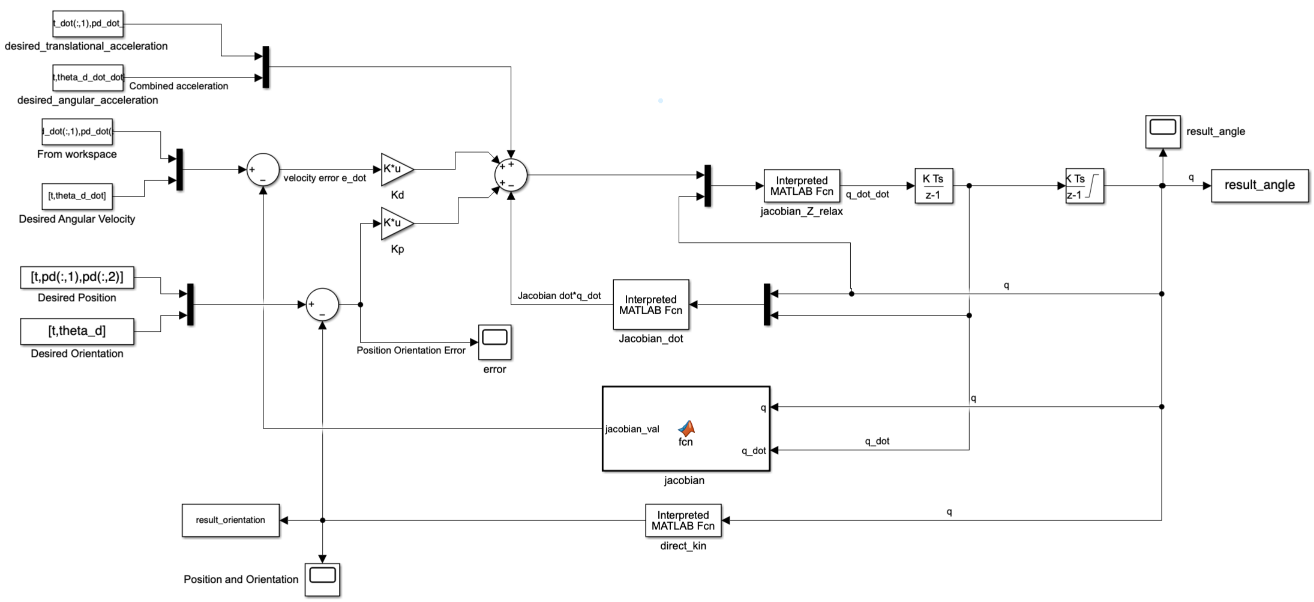


Figure 4: Simulink block diagram for Jacobian pseudo inverse.

Implemented second order kinematic inversion using Jacobian pseudo inverse for maximizing the distance from an obstacle along the path. The object is a sphere with center coordinates =

$$[0.4, 0.7, 0.5]^T$$

$$HT\_matrix = \begin{bmatrix} \cos(\theta_1+\theta_2+\theta_4) & -\sin(\theta_1+\theta_2+\theta_4) & 0 & a_2\ \cos(\theta_1+\theta_2)+a_1\ \cos(\theta_1) \\ \sin(\theta_1+\theta_2+\theta_4) & \cos(\theta_1+\theta_2+\theta_4) & 0 & a_2\ \sin(\theta_1+\theta_2)+a_1\ \sin(\theta_1) \\ 0 & 0 & 1 & base-d3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}$$

$$jacobian\_matrix = \begin{bmatrix} -a_2\ \sin(\theta_1+\theta_2)-a_1\ \sin(\theta_1) & -a_2\ \sin(\theta_1+\theta_2) & 0 & 0 \\ a_2\ \cos(\theta_1+\theta_2)+a_1\ \cos(\theta_1) & a_2\ \cos(\theta_1+\theta_2) & 0 & 0 \\ 1 & 1 & 0 & 1 \end{bmatrix} \tag{2}$$

$$jacobian\_dot\_pre = \begin{bmatrix} -a_2\ \cos(\theta_1+\theta_2)*(\theta_1+\theta_2)-a_1\ \cos(\theta_1)*\theta_1 & -a_2\ \cos(\theta_1+\theta_2)*(\theta_1+\theta_2) & 0 & 0 \\ -a_2\ \sin(\theta_1+\theta_2)*(\theta_1+\theta_2)-a_1\ \sin(\theta_1)*(\theta_1) & -a_2\ \sin(\theta_1+\theta_2)*(\theta_1+\theta_2) & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \tag{3}$$

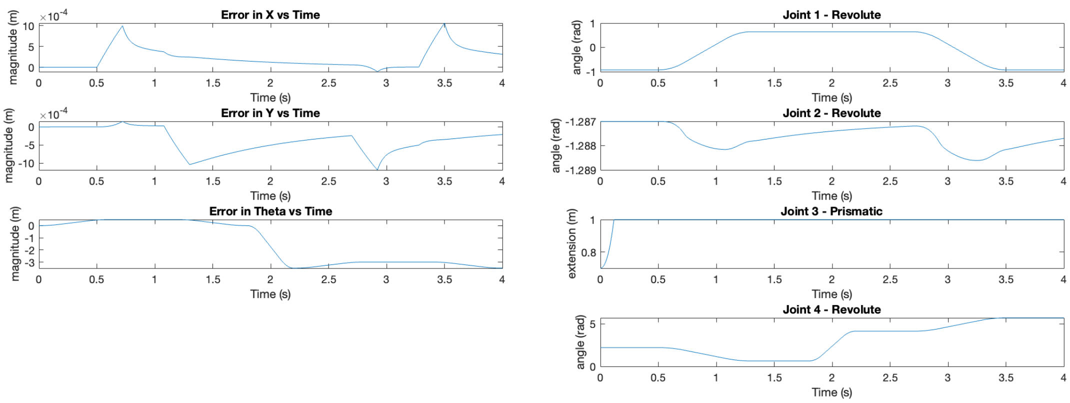
$$jacobian\_dot = jacobian\_dot\_pre \cdot q\_dot \tag{4}$$

$$\ddot{q} = J_A^{\dagger}(\ddot{x}_d + K_d\dot{e} + K_p e - \dot{J}_A(q,\dot{q})\dot{q}) + (I_n - J_A^{\dagger}J_A)\ddot{q}_0 \tag{5}$$

$$w(q) = \min_{p,\mathbf{O}} \|p(q) - \mathbf{O}\| \tag{6}$$

$$\dot{q}_0 = k_0 \left(\frac{\partial w(q)}{\partial q}\right)^T \tag{7}$$

Graphs



(a) (b)

Figure 5: Graphs generated for Jacobian pseudo inverse of SCARA. **(a)** Error in Operational space of X, Y, and Theta across time. **(b)** Value of joint angles / extension across time.