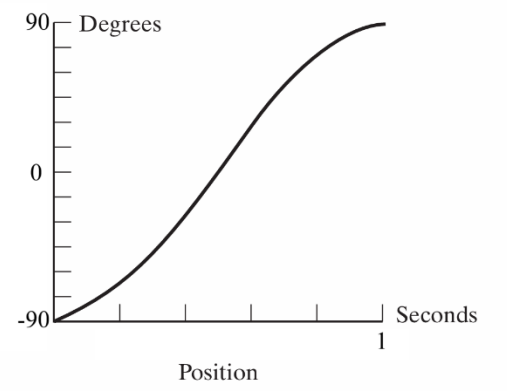
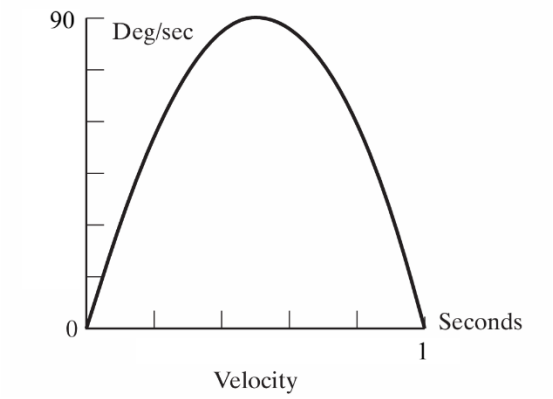
Trajectory Generation

Velocity Profile

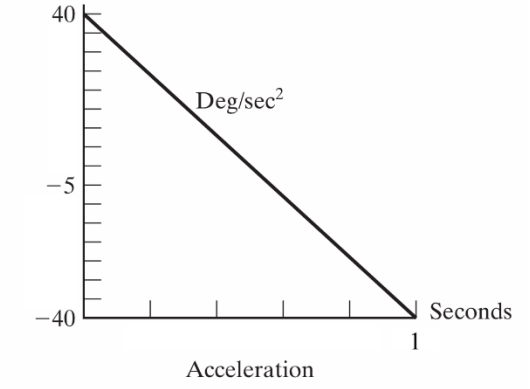
We have chosen this velocity profile since there is no need to have a nonstandard movement. Also, the values of 1 second and 90 degrees were taking into account to achieve a complete retraction or contraction of the planar arm within 1 second.



Position



Velocity



Acceleration

Singularities

Singularity Type 1: Planar arm alignment (elbow singularities)

The 3R planar chain becomes singular when the revolute links align. Basically, when θ3 equals 0 or π (which may not happen due

Jacobian

$$[\mathbf{q} = \begin{bmatrix} d & \theta_2 & \theta_3 & \theta_4 \end{bmatrix}^T]$$

$$[\mathbf{x} = \begin{bmatrix} x & y & z & \phi \end{bmatrix}^T]$$

$$[J = \begin{bmatrix} 0 & -L_1 \sin\theta_2 - L_2 \sin(\theta_2+\theta_3) - L_3 \sin(\theta_2+\theta_3+\theta_4) & -L_2 \sin(\theta_2+\theta_3) - L_3 \sin(\theta_2+\theta_3+\theta_4) & -L_3 \sin(\theta_2+\theta_3+\theta_4) \\ 0 & L_1 \cos\theta_2 + L_2 \cos(\theta_2+\theta_3) + L_3 \cos(\theta_2+\theta_3+\theta_4) & L_2 \cos(\theta_2+\theta_3) + L_3 \cos(\theta_2+\theta_3+\theta_4) & L_3 \cos(\theta_2+\theta_3+\theta_4) \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 \end{bmatrix}]$$

Forward Kinematics

$$[\begin{matrix} x = L_1 \cos\theta_2 + L_2 \cos(\theta_2+\theta_3) + L_3 \cos(\theta_2+\theta_3+\theta_4) \\ y = L_1 \sin\theta_2 + L_2 \sin(\theta_2+\theta_3) + L_3 \sin(\theta_2+\theta_3+\theta_4) \\ z = d \\ \phi = \theta_2 + \theta_3 + \theta_4 \end{matrix}]$$

$$[\det(J) = L_2 L_3 \sin(\theta_3)]$$