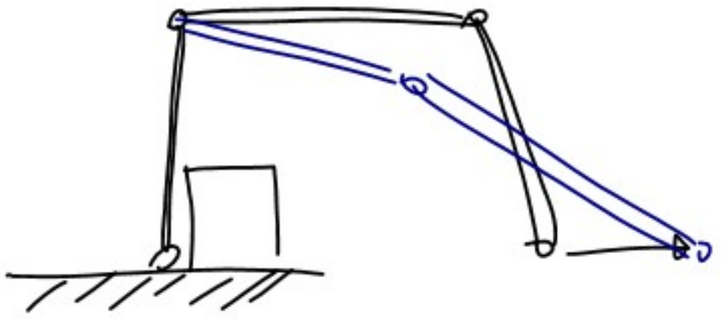
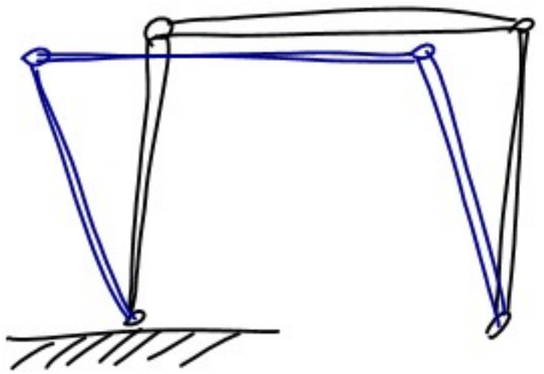
Joint Limits



$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = \underbrace{\begin{bmatrix} \partial x/\partial\theta_1 & \partial x/\partial\theta_2 & \partial x/\partial\theta_3 \\ \partial y/\partial\theta_1 & \partial y/\partial\theta_2 & \partial y/\partial\theta_3 \end{bmatrix}}_{J} \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \end{bmatrix}$$

$$\begin{bmatrix} 0 & \partial x/\partial\theta_2 & \partial x/\partial\theta_3 \\ 0 & \partial y/\partial\theta_2 & \partial y/\partial\theta_3 \end{bmatrix}$$

Nullspace Control



$$J = J J^{+} J$$

$$0 = J - J J^{+} J$$

$$0 = J (I - J^{+} J)$$

$$\dot{\underline{x}} = J (I - J^{+} J) \dot{q}$$

$$J \dot{\theta} = J (I - J^{+} J) \dot{q}$$

$$\dot{\theta} = (I - J^{+} J) \dot{q}$$

$$\dot{\underline{x}} = J \dot{\theta}$$