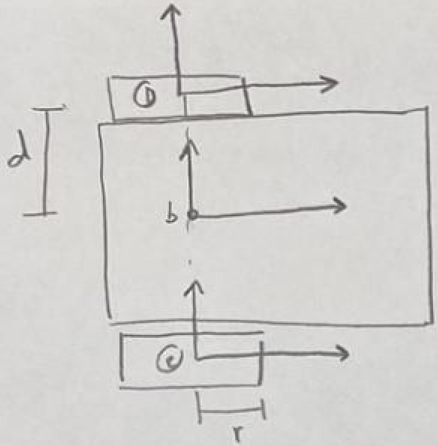


$$\mathcal{V}_b = \begin{bmatrix} \dot{\theta} \\ v_x \\ v_y \end{bmatrix}$$

$$T_{1b} = T(0, 0 - d) \quad \& \quad T_{2b} = T(0, 0, d)$$

$$\mathcal{V}_1 = A_{1b} \mathcal{V}_b$$

$$\begin{bmatrix} \dot{\theta}_1 \\ v_{x_1} \\ v_{y_1} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ -d & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ v_x \\ v_y \end{bmatrix} = \begin{bmatrix} \dot{\theta} \\ -d\dot{\theta} + v_x \\ v_y \end{bmatrix}$$

$$\begin{bmatrix} \dot{\theta}_1 \\ r\dot{\phi}_1 \\ 0 \end{bmatrix} = \begin{bmatrix} \dot{\theta} \\ -d\dot{\theta} + v_x \\ v_y \end{bmatrix} \quad \text{so,} \quad \dot{\phi}_1 = -\frac{d}{r}\dot{\theta} + \frac{v_x}{r}$$

$$\begin{bmatrix} \dot{\phi}_1 \\ 0 \end{bmatrix} = \begin{bmatrix} -\frac{d}{r} & \frac{1}{r} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ v_x \\ v_y \end{bmatrix}$$

$$\dot{\phi}_1 = \frac{1}{r} \begin{bmatrix} -d & 1 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ v_x \\ v_y \end{bmatrix}$$

by symmetry $\dot{\phi}_2 = \frac{1}{r} \begin{bmatrix} d & 1 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ v_x \\ v_y \end{bmatrix}$

$$\dot{\phi} = H \mathcal{V}_b$$

$$\begin{bmatrix} \dot{\phi}_1 \\ \dot{\phi}_2 \end{bmatrix} = \begin{bmatrix} u_L \\ u_R \end{bmatrix} = \frac{1}{r} \begin{bmatrix} -d & 1 & 0 \\ d & 1 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ v_x \\ v_y \end{bmatrix} \qquad \underline{(\text{Eq } 1)}$$

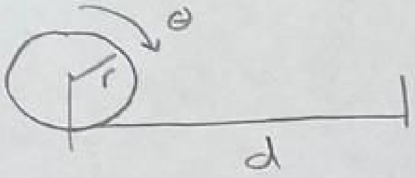
$$\mathcal{V}_b = H^{+} u$$

$$H^{+} = (H^T H)^{-1} H^T \quad \text{(linearly independent columns)}$$

$$H^{+} = H^T (H H^T)^{-1} \quad \text{(rows)}$$

$$H^{+} = r \begin{bmatrix} -\frac{1}{2d} & \frac{1}{2d} \\ \frac{1}{2} & \frac{1}{2} \\ 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} \dot{\theta} \\ v_x \\ v_y \end{bmatrix} = r \begin{bmatrix} -\frac{1}{2d} & \frac{1}{2d} \\ \frac{1}{2} & \frac{1}{2} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} u_L \\ u_R \end{bmatrix} = r \begin{bmatrix} \frac{u_R - u_L}{2d} \\ \frac{u_L + u_R}{2} \\ 0 \end{bmatrix} \qquad \underline{(\text{Eq } 2)}$$



$d = r\theta$ $\qquad$ $\Delta t = 1$ $\qquad$ $\dot{\phi} = \begin{bmatrix} u_L \\ u_R \end{bmatrix} = \phi$

$\Delta\phi = H(0)V_b$

no chassis orientation dependence

$HH^+ = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

So, $\Delta\phi = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} u_L \\ u_R \end{bmatrix}$

$\begin{bmatrix} \Delta\phi_L \\ \Delta\phi_R \end{bmatrix} = \begin{bmatrix} u_L \\ u_R \end{bmatrix}$ (Eq 3)

$\Delta\phi = HH^+ u$ $\quad$ & $\quad V_b = H^+\Delta\phi$

measurements or controls

$V_b = r\begin{bmatrix} -\frac{1}{2d} & \frac{1}{2d} \\ \frac{1}{2} & \frac{1}{2} \\ 0 & 0 \end{bmatrix}\begin{bmatrix} \Delta\phi_L \\ \Delta\phi_R \end{bmatrix}$