$$v = -\frac{x^T P B\, P(x,t)}{\|x^T P B\|}$$

Denote $\underline{w = x^T P B}$

$$x = \begin{bmatrix} e \\ \dot{e} \end{bmatrix} = \begin{bmatrix} q - q_d \\ \dot{q} - \dot{q}_d \end{bmatrix}$$

$$\dot{V} = -x^T Q x + 2x^T P B\,(v + \eta)$$

$$= -x^T Q x + 2w\left(-\frac{w}{\|w\|} P(x,t) + \eta\right)$$

$$2\left(-\frac{\|w\|^2}{\|w\|} P(x,t) + w\eta\right)$$

$$2\left(-\|w\| P(x,t) + w\eta\right)$$

$a + b$

$\leq \|a\| + \|b\|$

Cauchy-schwarz inequality

$$\leq 2\left(-\|w\| P(x,t) + \|w\|\,\|\eta\|\right)$$

$$= 2\|w\|\left(\underbrace{-P(x,t) + \|\eta\|}_{\leq 0}\right)$$

$\rho(\overset{x}{\cancel{q}}, t)$?

E

$\hat{C} = C - \bar{C}$

$$\eta(a_q, q, \dot{q}) = \underline{(M^{-1}\bar{M} - I)}\, a_q + M^{-1}(\hat{C}\dot{q} + \hat{N})$$

? $a_q = \ddot{q}^d - K_p e - K_D \dot{e} + \underline{v}$

$$\eta(a_q, q, \dot{q}) = \eta(q, \dot{q}, v)$$

$$= E(\ddot{q}^d - K_p e - K_D \dot{e} + v) + M^{-1}(\hat{C}\dot{q} + \hat{N})$$

$$= Ev + E\ddot{q}^d - EK_p e - EK_D \dot{e} + M^{-1}(\hat{C}\dot{q} + \hat{N})$$

$$\le \|E\| \underset{\Delta}{v} + \gamma_1 \|\overset{x}{\cancel{q}}\| + \gamma_2 \|\overset{x}{\cancel{q}}\|^2 + \gamma_3 \quad (\text{Assumption})$$

select $\gamma_1, \gamma_2, \gamma_3$. to determine $\underline{\rho(\overset{x}{\cancel{q}}, t)}$

use $\rho(\overset{x}{\cancel{q}}, t)$ to determine v.

check always that $\|\eta\| \le \rho(\overset{x}{\cancel{q}}, t)$

$$\le \|\vec{E}\|\,\|v\| + \gamma_1 \|\underset{x}{\cancel{q}}\| + \gamma_2 \|\underset{x}{\cancel{q}}\|^2 + \gamma_3$$

$$\begin{cases} v = -\dfrac{x^T PB\, \rho(x,t)}{\|x^T PB\|} \\ \|v\| = \rho(x,t) \end{cases}$$

$\rho(x,t) \geq \|\eta\|$

$$\|\eta\| \leq \|E\|\,\rho(x,t) + \underline{\gamma_1}\|x\| + \underline{\gamma_2}\|x\|^2 + \underline{\gamma_3} \leq \rho(x,t)$$

$\|E\| < 1$

$$E = M^{-1}\bar{M} - I$$

$$\|E\| = \|\underset{\substack{\uparrow \\ \text{true}}}{M^{-1}}\ \underset{\substack{\uparrow \\ \text{model}}}{\bar{M}} - I\| < 1$$

M and $\bar{M}$ must be close.

suppose: $M^L \precapprox M^{-1} \precapprox M^u$

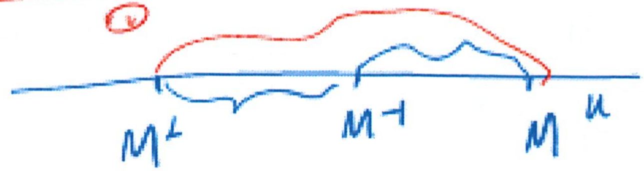
$\begin{bmatrix} \times & \times \\ \times & \times \end{bmatrix} \precapprox \begin{bmatrix} \cdot & \cdot \\ \cdot & \cdot \end{bmatrix}$

$$\boxed{\bar{M} \approx \frac{2}{M^L + M^u} \quad \text{elementwise.}}$$

$x \leq 0$

$$\|M^{-1}\bar{M} - I\| \leq \|M^{-1} \cdot \frac{2}{M^L + M^u} - I\| = \|\underbrace{\frac{2M^{-1} - M^L - M^u}{M^L + M^u}}_{①}\| < 1$$

use : $\| m^{T} - m^{u} + m^{T} - m^{L} \| < \| m^{u} - m^{L} \|$



$$\frac{\| m^{u} - m^{L} \|}{\| m^{L} + m^{u} \|} < 1$$