$$\dot{x} = Fx + Gu \rightarrow \text{Eq. estados}$$

$$y = Hx + Ju \rightarrow \text{Eq. salida}$$

$$\frac{Y(s)}{U(s)} = H(sI - F)^{-1}G + J$$

(escalar)

<u>Regulador completo</u> de estados.

$$u(t) = -Kx(t)$$

$$K \Rightarrow 1 \times n$$

$$\det(sI - \underbrace{(F - GK)}_{\text{matriz m.f.}}) = \underbrace{\alpha(s)}_{\text{poli deseado.}}$$

Ackerman.

$$K = [0\ 0\ 0\ \dots\ 1]\, \mathcal{C}^{-1}\, \alpha(F)$$

$$\mathcal{C} = [G\ \ FG\ \ F^2G\ \dots\ F^{n-1}G]$$

$\alpha(F)$ = poli deseado $(s \rightarrow F)$

import control

K = control.acker(F, G, polos)

Exemplo:

$$G(s) = \frac{30}{s(s+1)^2}$$

$$G(s) = \frac{30}{s(s^2+2s+1)} = \frac{30}{s^3+2s^2+s}$$

FCC:

$$\dot{x} = \begin{pmatrix} -2 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} x + \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} u$$

$$\alpha(s) = (s-(-4+j4))(s-(-4-j4))(s-(-12))$$

$$= (s+4-j4)(s+4+j4)(s+12)$$

$$= s^3 + 20s^2 + 128s + 384$$

$$K_J = [0 \quad 0 \quad 1]\, \mathcal{C}^{-1} \cdot \alpha(F)$$

$$\mathcal{C} = [G \quad FG \quad F^2G]$$

$$K = [18 \quad 127 \quad 384]$$

P/ simular:

$$\dot{x} = \underbrace{(F - GK)}_{}x + \underline{0}_3 u$$

$$y = I_3 x + 0_3 u$$

$$x = \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \end{bmatrix}$$

$$= \begin{bmatrix} x_1(0) & x_1(0{,}1) & x_1(0{,}2) & x_1(0{,}3) & \cdots \\ & & & & \\ & & & & \end{bmatrix}$$

$$y = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ -Kx \end{bmatrix} = \begin{bmatrix} I_3 \\ -K \end{bmatrix} x$$

$$F = \begin{pmatrix} 0 & 1 \\ -\omega_0^2 & 0 \end{pmatrix} \qquad G = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

$$H = \begin{pmatrix} 1 & 0 \end{pmatrix} \qquad J = 0$$

$$\begin{pmatrix} F & G \\ H & J \end{pmatrix} v = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

$$\underbrace{\left(\begin{array}{cc|c} 0 & 1 & 0 \\ -\omega_0^2 & 0 & 1 \\ \hline 1 & 0 & 0 \end{array}\right)}_{M} v = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

$$\omega_0 = 1$$

$$v = \begin{pmatrix} v_1 \\ v_2 \\ \hdashline v_3 \end{pmatrix} \begin{matrix} \left.\vphantom{\begin{matrix} a \\ b \end{matrix}}\right\} N_x \\ \left.\vphantom{a}\right\} N_u \end{matrix} = \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$$

$$N_x = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \qquad \underline{N_u = 1}$$

$$K = \begin{pmatrix} 3\omega_0^2 & 4\omega_0 \end{pmatrix} = \begin{pmatrix} 3 & 4 \end{pmatrix}$$

$$N = \begin{pmatrix} 3 & 4 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix} + 1$$

$$= 3 \cdot 1 + 4 \cdot 0 + 1 = 4$$

$$u = -\begin{pmatrix} 3 & 4 \end{pmatrix} x + 4 r$$

$$\dot{x} = F\cancel{x + G}u$$

$$y = Hx$$

$$u = -Kx \quad + Nr$$

$$\dot{x} = Fx + G(-Kx + Nr)$$

$$= Fx - GKx + GNr$$

$$= (F - GK)x + GNr$$