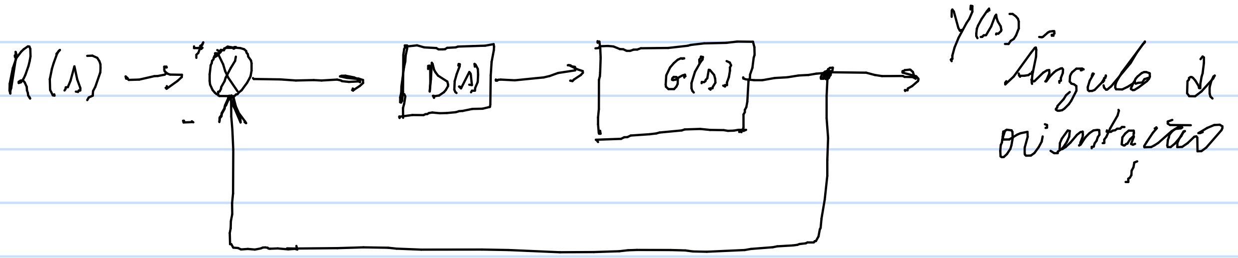
1) Controle de orientação de um satélite espacial



2)

$$G(s) = \frac{10}{(s+1)(s+9)}$$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -10 & -9 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$$

$$y = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

$$\frac{Y(s)}{U(s)} = \frac{10}{s^2 + 10s + 9}$$

$$s^2 Y(s) + 10 s Y(s) + 9 Y(s) = 10 U(s)$$

$\mathcal{L}^{-1} \Downarrow$

$$\ddot{y}(t) + 10 \dot{y}(t) + 9 y(t) = 10 \cdot u(t)$$

Considerando a entrada do sistema a posição desejada, e a saída a velocidade angular e o ângulo, temos

$$\ddot{\theta}(t) + 10 \dot{\theta}(t) + 9 \theta(t) = 10 u(t)$$

Entrada: ? torque
Saída: ? θ

//

3) $\frac{Y(s)}{U(s)} \cdot \frac{10}{s^2+10s+9}$ => polos 9 e 1

$s_1 \rightarrow 9 : \tau = \frac{1}{9}$
$s_2 \rightarrow 1 : \tau = 1s$

Malha aberta:

$K_0 = \frac{10}{9}$ $\omega_n = 3$, $2\zeta\omega_n = 10$

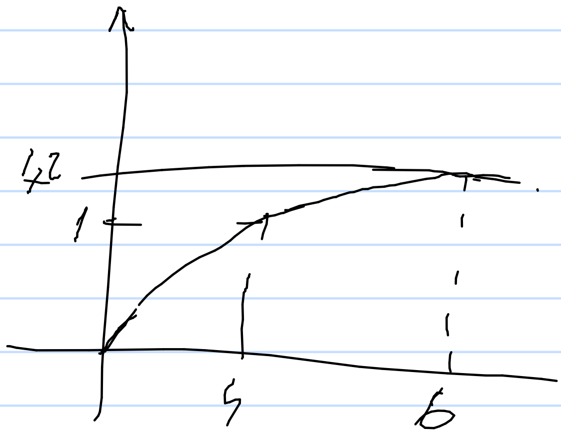
Freq Natu. N amortec.

$\zeta = \frac{10}{6} = 1,6667$

$G(s) = 1,1111 \cdot \frac{9}{s^2+10s+9}$ $\tau = \frac{1}{\zeta\omega_n}$ => $\tau = 0,1999s$

M.A: t_s: 6,45s

0,63 x Amplitude = 0,702
$\tau = 1,1$



Sobre amortecido

$\frac{K}{(\tau_1 s+1)(\tau_2 s+1)}$ τ dominante: Mais lento: 1s

---

3) $T = 20\% \ \tau$ => $T = 0,222$ s

4) $G(z) = \frac{0,1288 z + 0,06241}{z^2 - 0,9365 z + 0,1086}$ (Vai dar Ruim)

$G(z) = \frac{(z + 0,4845)}{(z - 0,8009)(z - 0,1356)}$

5) $$G(z) = \frac{0,1288z + 0,06241}{z^2 - 0,9365z + 0,1086}$$

$$G(z) = \frac{(z + 0,4845)}{(z - 0,8009)(z - 0,1356)}$$

Fazendo $z = \dfrac{1 + (T/2)w}{1 - (T/2)w}$ =>

$$G(w) = \frac{\left(\frac{1+0,111w}{1-0,111w}\right) + 0,4845}{\left[\left(\frac{1+0,111w}{1-0,111w}\right) - 0,8009\right]\left[\left(\frac{1+0,111w}{1-0,111w}\right) - 0,1356\right]}$$

$\Downarrow$

Matlab:

$$G(w) = \frac{-0,03246w^2 - 0,5498w + 7,588}{w^2 + 7,853w + 6,829} \quad \begin{cases} w_{z1} = -25,9451 \\ w_{z2} = 9,0090 \\ w_{p1} = -6,8574 \\ w_{p2} = -0,9959 \end{cases}$$

Critério RH:

Polinômio característico: $w^2 + 7,853w + 6,829$

w^2	1	6,829
w^1	7,853	0
w^0	6,829	

Não houve troca de sinal, sistema só possui polos com parte real negativa. estável.

$$T(w) = \frac{K_c\, G(w)}{1 + K_c\, G(w)}$$

$$1 + K_c\left(\frac{-0,03246w^2 - 0,5498w + 7,588}{w^2 + 7,853w + 6,829}\right)$$

$$T(w) = \frac{k_c \; G(w)}{1 + k_c \; G(w)}\,,$$ Como $G(w)$ é SLIT 2ª ordem

$$1 + k_c \left(\frac{-0{,}03246w^2 - 0{,}5498w + 7{,}588}{w^2 + 7{,}853w + 6{,}829} \right) > 0$$

$$w^2 + 7{,}853w + 6{,}829 - 0{,}03246w^2 k_c - 0{,}5498wk_c + 7{,}588k_c > 0$$

$$(1 - 0{,}03246k_c)w^2 + (7{,}853 - 0{,}5498k_c)w + 7{,}588k_c + 6{,}829 > 0$$

$$\Downarrow$$

$$\begin{cases} 1 - 0{,}03246\,k_c > 0 \\ 7{,}853 - 0{,}5498\,k_c > 0 \\ 6{,}829 + 7{,}588\,k_c > 0 \end{cases} \Rightarrow \underbrace{\begin{matrix} k_c < 30{,}8071 \\ k_c < 14{,}2834 \\ k_c > -0{,}8999 \end{matrix}}$$

$$\boxed{0 < k_c < 14{,}2834}$$

---

6) verificar rlocus ok

---

7) $$e_{ss} = \lim_{z \to 1} \frac{z}{1 + K\,G(z)} = 0{,}05$$

$$\frac{1}{1 + K\left(\frac{0{,}1288 + 0{,}06241}{1 - 0{,}9365 + 0{,}1086}\right)} = 0{,}05$$

$$\frac{1}{1 + 1{,}11098K} = 0{,}05$$

$$0{,}05 + 0{,}0555K = 1$$

$$K = \frac{1 - 0{,}05}{0{,}0555} \Rightarrow \boxed{K = 17{,}1171}$$

Fora da faixa

$$\frac{1}{1 + 1{,}11098K} = e$$

p/ $K = 1$

$e = 0{,}4737$

$e = 47{,}37\%$

p/ $K = 14{,}2 < 14{,}2834$

$e = 0{,}05960$

$e = 5{,}96\%$

4) P/ $T = 10\%\, \tau \Rightarrow T = 0,11$

$$\boxed{G(z) = \frac{0,04293z + 0,02981}{z^2 - 1,267z + 0,3329}}$$

$$G(z) = \frac{z + 0,6944}{(z - 0,8958)(z - 0,3716)}$$

5)

$$G(w) = G(z)\Big|_{z = \frac{1 + (T/2)w}{1 - (T/2)w}}$$

$$\boxed{G(w) = \frac{-0,005045w^2 - 0,4168w + 9,247}{w^2 + 9,329w + 8,322}}$$

- RH

w^2	1	8,322
w^1	9,329	
w^0	8,322	

Não houve troca de sinal, sistema só possui polos com parte real negativa. Estável.

$$T(w) = \frac{K_c\, G(w)}{1 + K_c\, G(w)}$$ importa que $1 + K_c G(w) > 0$

$$w^2 + 9,329w + 8,322 + K_c(-0,005045w^2 - 0,4168w + 9,247) > 0$$

$$w^2(1 - 0,005045K_c) + w(9,329 - 0,4168K_c) + 9,247K_c + 8,322 > 0$$

$$\begin{cases} 1 - 0,005045K_c > 0 & \Rightarrow K_c < 198,2161 \\ 9,329 - 0,4168K_c > 0 & \Rightarrow K_c < 22,3824 \\ 8,322 + 9,247K_c > 0 & \Rightarrow \underbrace{K_c > -0,8999} \end{cases}$$

$$\boxed{0 < K_c < 22,3824}$$

6) OK (R locus)

$\boxed{0 < K_c < 22,3824}$ $G(z) = \dfrac{0,04293z + 0,02981}{z^2 - 1,267z + 0,3329}$

7) $e_{ss} = \lim\limits_{z \to 1} \dfrac{z}{1 + KG(z)} = 0,05$

$$\frac{1}{1 + K_c\left(\dfrac{0,04293 + 0,02981}{1 - 1,267 + 0,3329}\right)} = 0,05$$

$$= \frac{1}{1 + 1,1038K_c} = 0,05 \Rightarrow 0,05519K_c + 0,05 = 1$$

$\boxed{K_c = 17,2133}$ → Dentro da faixa

↳ $e = 0,4999$

Erros mínimos

$$\frac{1}{1 + 1,1038K} = e$$

p/ $K = 1$

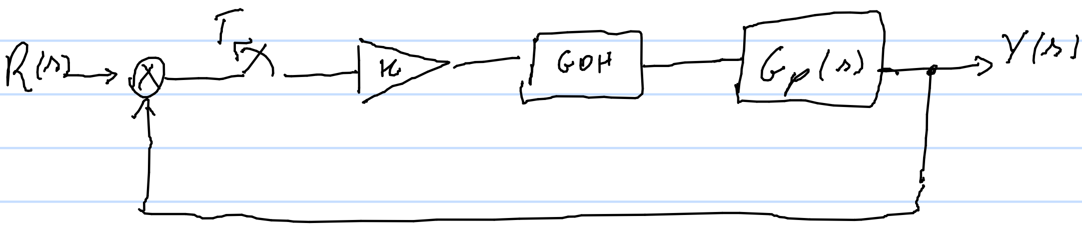
$e = 0,4753$

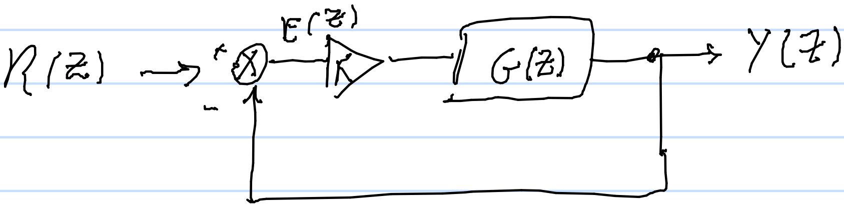
$e = 47,53\%$

p/ $K = 22,3 < 22,3824$

$e = 0,0390$

$e = 3,90\%$





$E(z) = R(z) - Y(z)$

$G_{mf}(z) = \dfrac{Y(z)}{R(z)} \Rightarrow R(z) = \dfrac{Y(z)}{G_{mf}(z)}$

8) Dead Beat

$$D(Z) = \frac{1}{G(Z)} \cdot \frac{Z^{-K}}{1 - Z^{-K}}$$, mas $K = 1$

$$D(Z) = \frac{1}{G(Z)} \cdot \frac{Z^{-1}}{1 - Z^{-1}} \frac{Z}{Z}$$

$$D(Z) = \frac{1}{G(Z)} \cdot \frac{1}{Z - 1}$$

p/ $T = 0,11$

$$D(Z) = \frac{23,296\,(Z - 0,8958)\,(Z - 0,3716)}{(Z + 0,6944)\,(Z - 1)}$$

Zeros: 0,8958 ; 0,3716

Polos: $-0,6944$, 1

$$M(Z) = \frac{D(Z)\,G(Z)}{1 + DG(Z)} = \frac{(Z - 0,8958)(Z - 0,3716)(Z + 0,6944)}{Z(Z - 0,3716)\,(Z - 0,8958)\,(Z + 0,6944)}$$

9) Dahlin

$$T_d(Z) = \frac{1 - e^{-T/\tau_d}}{1 - e^{-T/\tau_d} Z^{-1}} Z^{-K}$$, $K \geq 1$

$$q = e^{-T/\tau_d}$$

$$D(Z) = \frac{1}{G(Z)} \frac{(1 - q)\,Z^{-K}}{1 - q\,Z^{-1} - (1 - q)\,Z^{-K}}$$, $K \geq 1$, $\tau_{1\,G(Z)} = 0,999$
$\tau_{2\,G(Z)} = 0,1111$

Portanto, quero $\tau_d = 0,1111$ e $K = 1$,

$$D(Z) = \frac{1}{G(Z)} \frac{(1 - q)}{Z - q - (1 - q)}$$, $q = e^{-0,11/0,1111}$

$$D(Z) = \frac{1}{G(Z)} \frac{1 - q}{Z - 1}$$

Alocação de Polos:

$$G(Z) = \frac{(Z + 0,6944)}{(Z - 0,8958)(Z - .3716)}$$

$T = 0,9999$

$T = 0,1111$

Quero anular o polo mais lento.

RLocus $G(Z)$

$$D(Z) = \frac{(Z - 0,8958)(Z - 0,3716)}{(Z - 0,504)(Z - 1)}$$