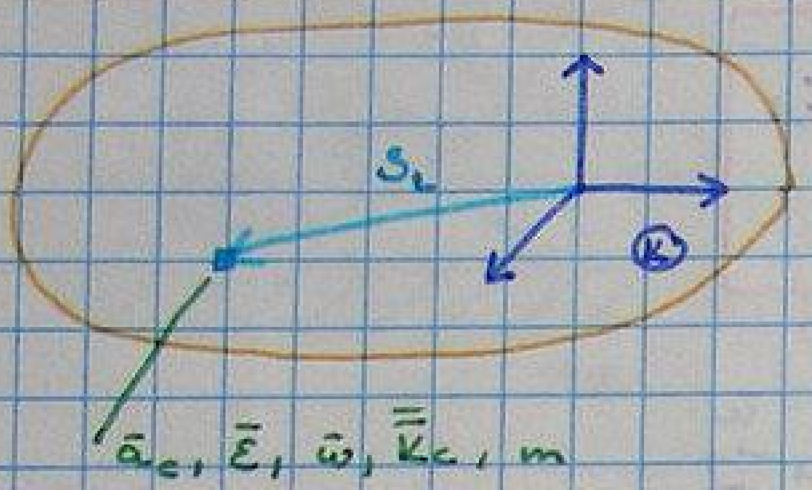
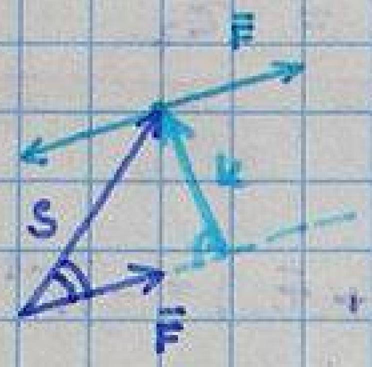
2009.03.18

Newton – Euler egyenletek

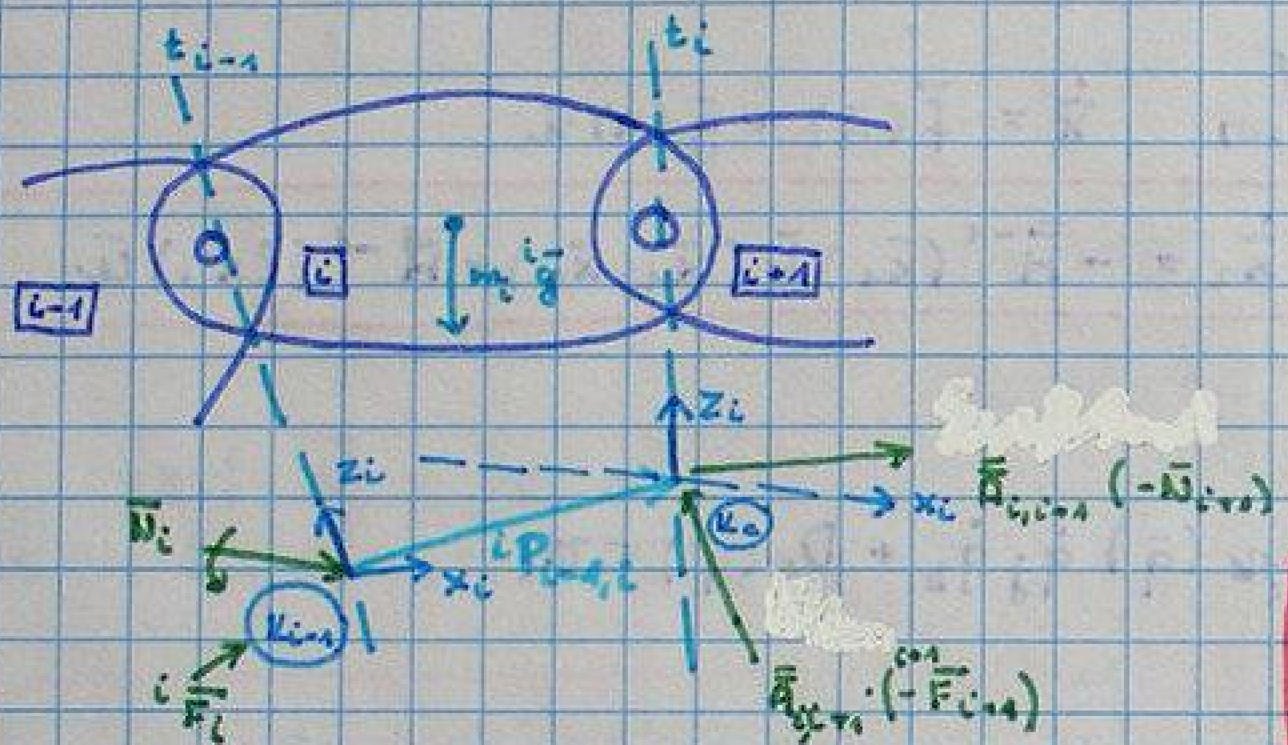


(1) $m\bar a_c = \bar F_{ext}$

(2) $\bar{\bar K}_c \bar\varepsilon + \bar\omega \times (\bar{\bar K}_c \bar\omega)^{\cdot} = \bar N_{ext}$



$\bar N = \bar F \times \bar S$



$$\boxed{m_i \bar a_{ci} = m_i\,{}^i\bar g + {}^i\bar F_i - \bar{\bar A}_{i,i+1}\,{}^{i+1}\bar F_{i+1}}$$

$$\Rightarrow \boxed{{}^i\bar F_i = m_i(\bar a_{ci} - {}^i\bar g) + \bar{\bar A}_{i,i+1}\,{}^{i+1}\bar F_{i+1}}$$

$$\bar{\bar K}_{ci}\,\bar\varepsilon_i + \bar\omega_i \times (\bar{\bar K}_{ci}\,\bar\omega_i) = {}^i\bar N_i + {}^i\bar F_i \times ({}^iP_{i-1,i} + \bar S_{ci}) - \bar{\bar A}_{i,i+1}\cdot{}^{i+1}\bar N_{i+1} - (\bar{\bar A}_{i,i+1}\cdot{}^{i+1}\bar F_{i+1}) \times \bar S_{ci}$$

$$\boxed{{}^i\bar N_i = \bar{\bar K}_{ci}\,\bar\varepsilon_i + \bar\omega_i \times (\bar{\bar K}_{ci}\,w_i) - {}^i\bar F_i \times ({}^i\bar P_{i-1,i} + \bar S_{ci}) + \bar{\bar A}_{i,i+1}\cdot{}^{i+1}\bar N_{i+1} + (\bar{\bar A}_{i,i+1}\cdot{}^{i+1}\bar F_{i+1}) \times \bar S_{ci}}$$

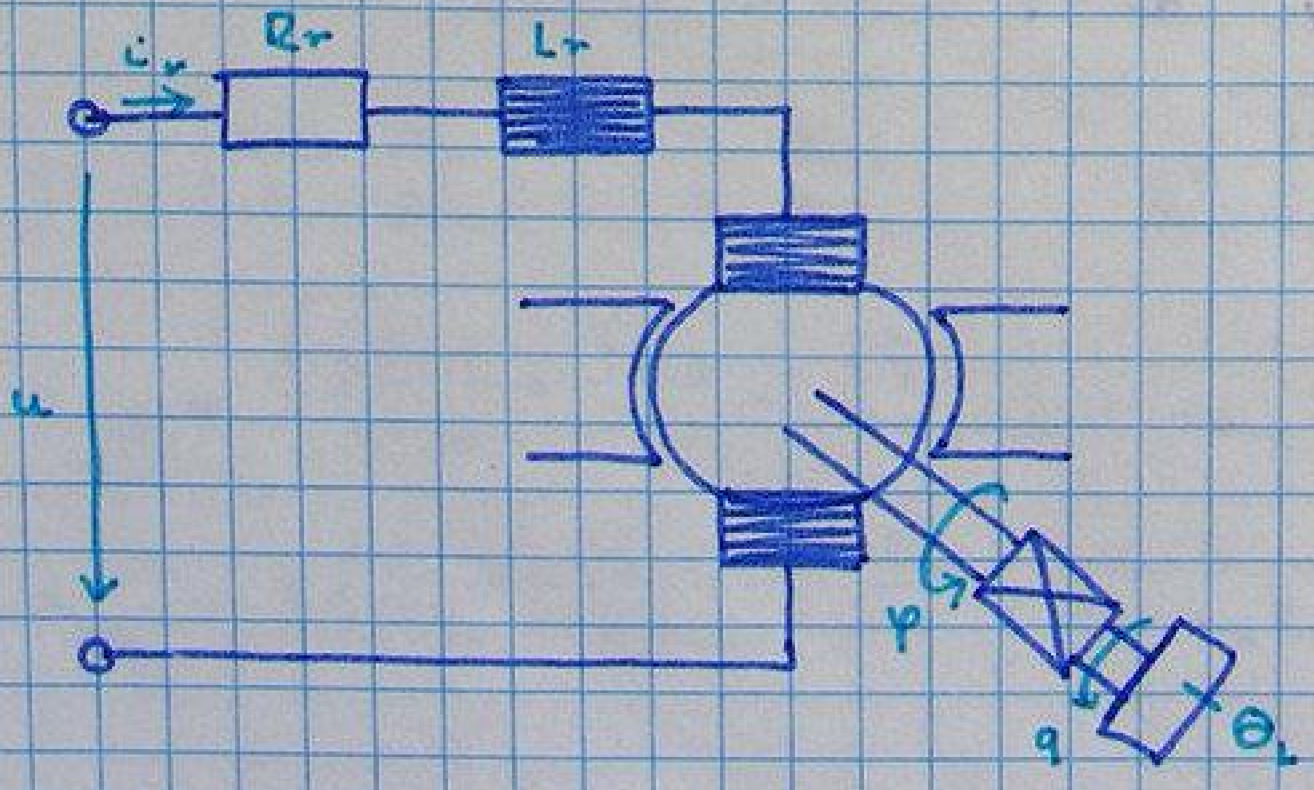
$${}^i P_{i-1,1} = \bar{\bar A}^T_{i-1,i}\,\bar P_{i-1,i}$$

$${}^i\bar t_{i-1} = \bar{\bar A}^T_{i-1,i}\begin{pmatrix}0\\0\\1\end{pmatrix} = \bar n_{i-1,i}$$

R csukló $\Rightarrow \tau_i = \bar n_{i-1,i}\cdot{}^i\bar N_i$

T csukló $\Rightarrow \tau_i = \bar n_{i-1,i}\cdot{}^i\bar F_i$

Aktuátor:



$\nu = \dfrac{\dot\varphi}{\dot q}$ áttétel

$R_r i_r + L_r \dfrac{di_r}{dt} = u - c_1\dot\varphi$

$\tau_m = c_2 i_r$

↳ torque (nyomaték)

$N_m = N_s \Leftrightarrow \tau_m\dot\varphi = \tau\dot q \Rightarrow \tau = \dfrac{\dot\varphi}{\dot q}\tau_m \Rightarrow \nu\tau_m$

m: motor oldal, s: szegmens oldal

Robot + motor + áttétel:

viszkózus súrlódás

$$\sum_j D_{ij}\,\ddot q_j + \sum_j\sum_k D_{ijk}\,\dot q_j\,\dot q_k + D_i + \Theta_{ri}\,\nu_i^2\,\ddot q_i + \nu_i f_{ri}\,\dot\varphi_i + f_{áll,i}\,\dot q_i = \tau_i = \nu_i c_{2i}\, i_{ri}$$

$$\tau_i = \nu_i c_{2i}\, i_{ri}$$

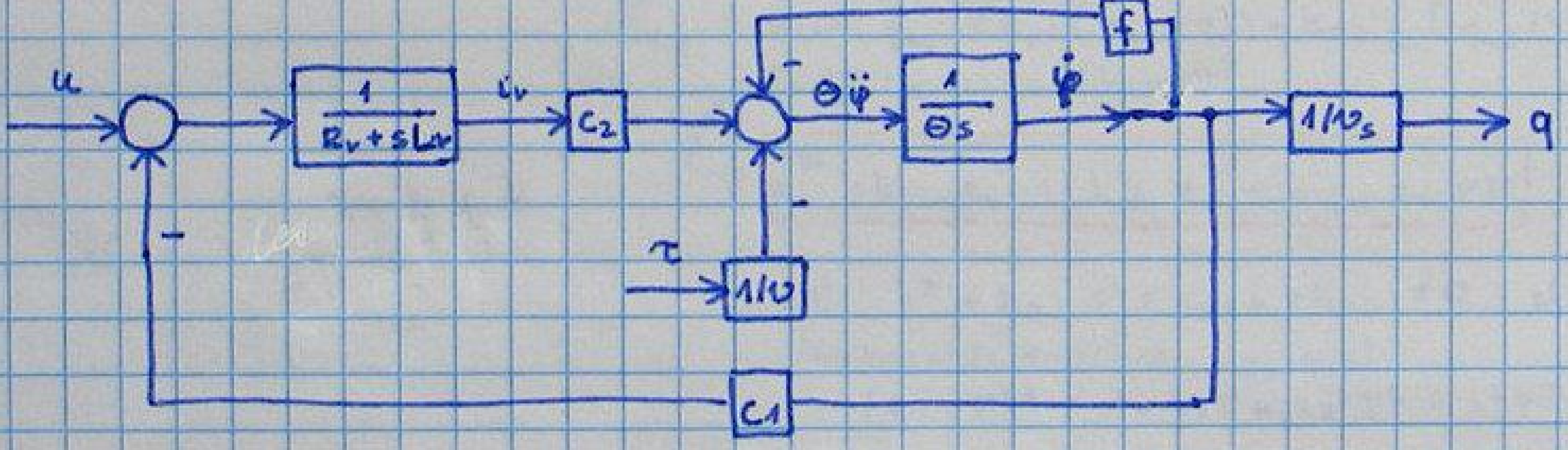
$$R_{ri}\, i_{ri} + L_{ri}\frac{di_{ri}}{dt} = u_i - c_{1i}\,\dot\varphi_i$$

Pálya: $q_a(t) \rightarrow \overline{D_{ii}\,(q_a(t))} = \bar D_{ii} \rightarrow \bar D_{ii}\,\ddot q_i$

$$(\bar D_{ii} + \nu_i^2\,\Theta_{ri})\,\ddot q_i + (f_{áll,r} + \nu_i^2 f_{ri})\,\dot q_i + \underbrace{\sum_j D_{ij}\,\ddot q_j + \sum_j\sum_k D_{ijk}\,\dot q_j\,\dot q_k + D_i - D_{ii}\,\ddot q_i}_{\tau_i^*\ \text{(zavarás)}} = \nu_i c_{2i}\, i_{ri}$$

$$\underbrace{\left(\Theta_{ri} + \frac{D_{ii}}{\nu_i^2}\right)}_{\Theta_i}\ddot\varphi_i + \underbrace{\left(f_{ri} + \frac{f_{áll,i}}{\nu_i^2}\right)}_{f_i}\dot\varphi_i = c_{2i}\, i_{ri} - \frac{\tau_i^*}{\nu_i}$$

$$\boxed{\begin{aligned} \Theta_i\,\ddot\varphi_i + f_i\,\dot\varphi_i &= c_{2i}\, i_{ri} - \frac{\tau_i^*}{\nu_i} \\ R_{ri}\, i_{ri} + L_{ri}\frac{di_{ri}}{dt} &= u_i - c_{1i}\,\dot\varphi_i \end{aligned}}$$



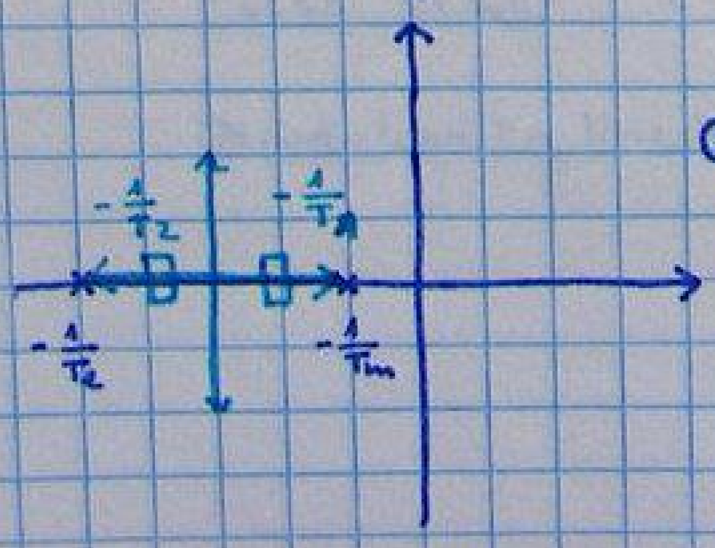
τ_i^* kiszabályozandó

$$\frac{\frac{1}{\Theta s}}{1 + \frac{1}{\Theta s} f} = \frac{1}{f + \Theta s} = \frac{1/f}{1 + s\underbrace{\frac{\Theta}{f}}_{T_m}}, \qquad \frac{1}{R_r + sL_r} = \frac{1/R_r}{1 + s\underbrace{\frac{L_r}{R_r}}_{T_e}}$$

$$W_{\varphi u} = \frac{\frac{1/R_r}{1+sT_e}\cdot c_2 \cdot \frac{1/f}{1+sT_m}}{1 + \frac{1/R_r}{1+sT_e}\cdot c_2 \cdot \frac{1/f}{1+sT_m}\cdot c_1} = \frac{\frac{c_2}{R_r f}}{(1+sT_m)(1+sT_e) + \frac{c_1 c_2}{R_r f}}$$

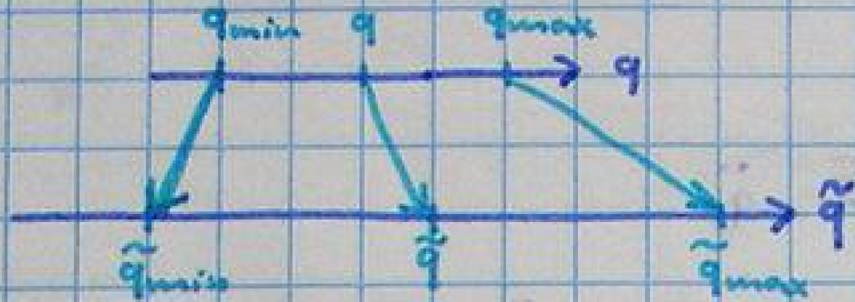
$$s^2\,T_m T_e + s(T_m T_e) + 1 + \frac{c_1 c_2}{R_r f} = 0$$

$$W_{\varphi u} = \frac{A}{1 + 2\xi T s + T^2 s^2} = \begin{cases} \xi > 1 \Rightarrow \dfrac{A}{(1+sT_1)(1+sT_2)} & T_1, T_2 \\ \xi < 1 \Rightarrow \dfrac{A}{1 + 2\xi T s + T^2 s^2} & \text{lengőtag} \end{cases}$$



Decentralizált (tengelyenkénti) 3-hurkos kaszkád szabályozás

belső áramszabályozás: analóg PI
középső fordulatszámszabályozás: analóg PI
külső pozíciószabályozás: mintavételes PID
érzékelők: $\tilde{q}$ "számláló" (3-hurkos, forgásirányfüggő)



$\tilde{\iota}$ feszültség: $\tilde{\iota} = \gamma\, i_r$
$\tilde{n}$ feszültség: $\tilde{n} = \delta\, \dot{\varphi}$