RETE PID

INNER LOOP NON CAMBIA

OUTER LOOP

$$\underline{v}_c := -K_P \underline{e} - K_D \underline{\dot{e}} - K_I \int \underline{e}\, dt$$

P D I

$$\begin{cases} \underline{\dot{\xi}} = F \underline{\xi} + G \underline{\varepsilon} \\ \underline{v}_c = H \underline{\xi} + L \underline{\varepsilon} \end{cases}$$

REGOLATORE DINAMICO

$$\Downarrow$$

$$\underline{\varepsilon} = \begin{bmatrix} \underline{e} \\ \underline{\dot{e}} \end{bmatrix}$$

$$\dot{\xi} = G\varepsilon$$

$$v_c = H\xi + L\varepsilon$$

Con $G = [I_n \quad 0]$

$$H = -K_I$$

$$L = [-K_P \quad -K_D]$$

$$\underline{\varepsilon} = \begin{bmatrix} e \\ \cancel{\dot e} \end{bmatrix}$$

non serve

$$\xrightarrow{\dot z \,=\, e} \boxed{\frac{1}{s}} \xrightarrow{z \,=\, \int e} \boxed{-K_I} \longrightarrow$$

$$\ddot e(t) + K_D \dot e(t) + K_p e(t) + K_I \int e\,dt = 0$$

$$\int e\,dt = z(t)$$

$$\dddot z(t) + K_D \ddot z(t) + K_p \dot z(t) + K_I z(t) = 0$$

$$\Downarrow \mathcal{L}(s)$$

$$\underbrace{\left(Is^2 + K_D s + K_p + \frac{1}{s} K_I\right)}_{P(s)} e(s) = 0$$

$P(s)$ polinomio caratteristico

$$Is^3 + K_D s^2 + K_p s + K_I = P(s)$$

$$\begin{bmatrix} \dot{\xi} \\ \dot{\varepsilon}_1 = \dot{e} \\ \dot{\varepsilon}_2 = \ddot{e} \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & I_n & 0 \\ 0 & 0 & I_n \\ -K_I & -K_P & -K_D \end{bmatrix}}_{A_c} \begin{bmatrix} \xi \\ \varepsilon_1 = e \\ \varepsilon_2 = \dot{e} \end{bmatrix}$$

LINEARIZZAZIONE APPROSSIMATA

$\eta \neq 0$

$\hat{M} \neq M(\underline{q})$

$\hat{h} \neq h(\underline{q}, \dot{\underline{q}})$

$$\Downarrow$$

$$\dot{\varepsilon} = A\varepsilon + Bv_c - B\eta$$

PD

$$\dot{\varepsilon} = A_c\varepsilon - B\eta$$

SEGNALE ECCITANTE SULL'ERRORE

PD

SE $\underline{v}_c = -K\underline{\varepsilon}$

$$\eta = E(q)(\ddot{\underline{q}}_r + K\underline{\varepsilon}) - $$
$$- M^{-1}(\underline{q})\,\Delta h(\underline{q}, \dot{\underline{q}})$$

RETE PD $\boxed{\text{CON COMPENSAZIONE DI GRAVITA'}}$

$\hat{M} = I$

$\hat{h} = g(\underline{q}) - \ddot{q}_r$

$u_c := \hat{M}(\ddot{q}_r - v_c) + \hat{h}$

$$v_c := K_D \dot{\underline{e}} + K_P \underline{e} + g(\underline{q})$$

$$M(\underline{q})\ddot{\underline{q}} + C(\underline{q}, \dot{\underline{q}})\dot{\underline{q}} + B_t \dot{\underline{q}} + g(\underline{q}) =$$

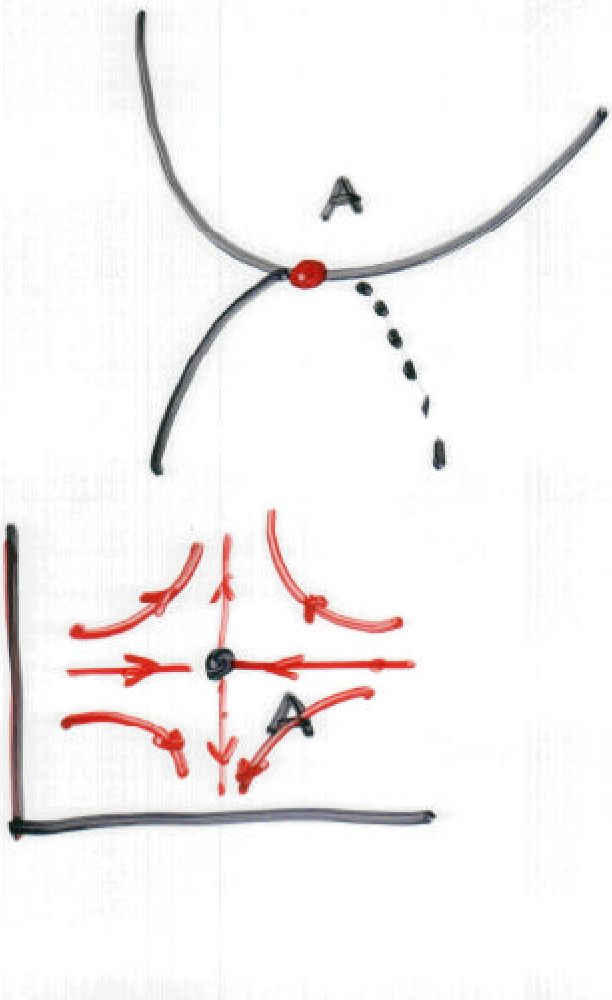
$$= K_D \dot{\underline{e}} + K_P \underline{e} + g(\underline{q})$$

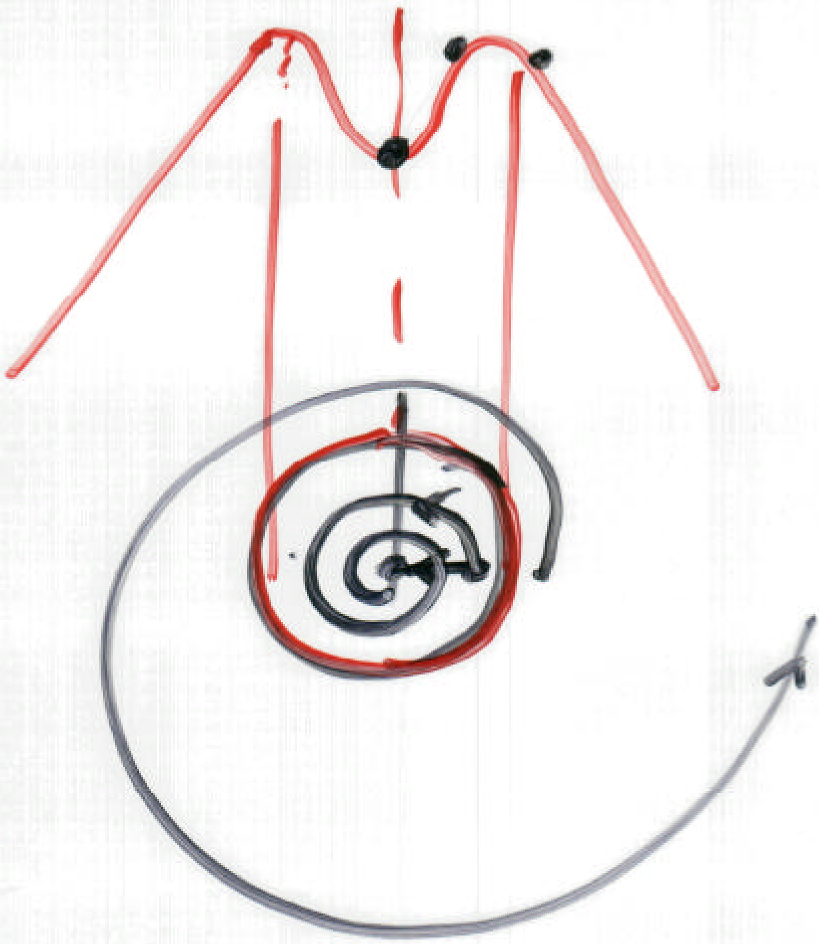
SE PONIAMO $\dot{q}_r = 0$ OTTENIAMO

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + (K_D + B_t)\dot{q} - K_P e = 0$$

$$\Downarrow$$

LO SCHEMA GARANTISCE L'ASINTOTICA STABILITÀ DELL'IMPIANTO CONTROLLATO

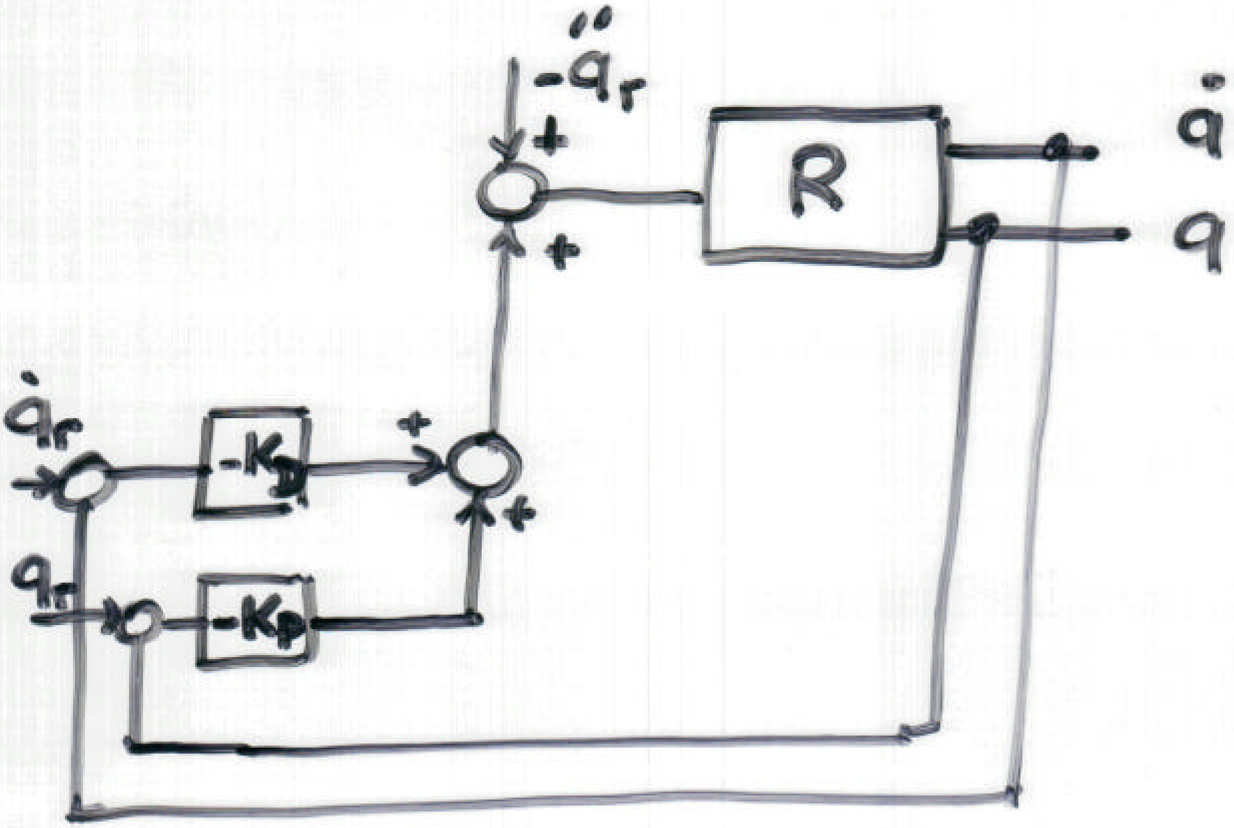




CONTROLLO A GIUNTI INDIPENDENTI

$$\hat{M} = I$$

$$\hat{h} = -\ddot{q}_r$$



CONTROLLO DINAMICA INVERSA FEEDFORWARD

COPPIA CALCOLATA

$\hat{M} = M(q_r)$
$\hat{h} = h(q_r, \dot{q}_r)$

INVECE DELLE MISURE USO I RIFERIMENTI