a

$$J = (\hat{Y} - Ref)^T Q (\hat{Y} - Ref) + \Delta\hat{U}_{mpc}^T R \Delta\hat{U}_{mpc} + \hat{U}_{mpc}^T \bar{R} \hat{U}_{mpc} \quad (1)$$

$$\hat{Y} = f_y\, x(k) + P_y \hat{U}_{mpc} \quad (2)$$

$$\hat{U}_{mpc} = f_u u_{mpc}(k-1) + P_u \Delta\hat{U}_{mpc} \quad (3)$$

$\hookrightarrow R^{n_u N_u,\, n_u}$

(3) → (2)

$$\hat{Y} = f_y\, x(k) + P_y f_u u_{mpc}(k-1) + P_y P_u \Delta\hat{U}_{mpc} \quad (4)$$

(4), (3) → (1)

$$J = \left(f_y x(k) + P_y f_u u_{mpc}(k-1) + P_y P_u \Delta\hat{U}_{mpc}\right)^T Q \left(f_y x(k) + P_y f_u u_{mpc}(k-1) + P_y P_u \Delta\hat{U}_{mpc}\right)$$
$$+ \Delta\hat{U}_{mpc}^T R \Delta\hat{U}_{mpc} +$$
$$+ \left(f_u u_{mpc}(k-1) + P_u \Delta\hat{U}_{mpc}\right)^T \bar{R} \left(f_u u_{mpc}(k-1) + P_u \Delta\hat{U}_{mpc}\right)$$

$$J = \Delta\hat{U}_{mpc}^T P_u^T P_y^T Q P_y P_u \Delta\hat{U}_{mpc} + 2\left(f_y x(k) + P_y f_u u_{mpc}(k-1)\right)^T Q P_y P_u \Delta\hat{U}_{mpc} +$$
$$+ \Delta\hat{U}_{mpc}^T R \Delta\hat{U}_{mpc} +$$
$$+ \Delta\hat{U}_{mpc}^T P_u^T \bar{R} P_u \Delta\hat{U}_{mpc} + 2\left(f_u u_{mpc}(k-1)\right)^T \bar{R} P_u \Delta\hat{U}_{mpc} + cte$$

(2)

$$J = \Delta \hat{U}_{mpc} \left(P_u^T P_y^T Q P_y P_u + R + P_u^T \bar{R} P_u \right) \Delta \hat{U}_{mpc} +$$

$$+ 2 \left\{ \left(\begin{bmatrix} F_y & P_y F_u \end{bmatrix} \begin{bmatrix} x(k) \\ u_{mpc}(k-1) \end{bmatrix} \right)^T Q P_y P_u + \left(F_u u_{mpc}(k-1) \right)^T \bar{R} P_u \right\} \Delta \hat{U}_{mpc} + cte$$

$$J = \Delta \hat{U}_{mpc}^T \underbrace{\left(P_u^T P_y^T Q P_y P_u + R + P_u^T \bar{R} P_u \right)}_{H_{qp}} \Delta \hat{U}_{mpc} +$$

$$+ 2 \left\{ \begin{bmatrix} x^T(k) & u_{mpc}^T(k-1) \end{bmatrix} \begin{bmatrix} F_y^T \\ F_u^T P_y^T \end{bmatrix} Q P_y P_u + u_{mpc}^T(k-1) F_u^T \bar{R} P_u \right\} \Delta \hat{U}_{mpc} + cte$$

$$J = \Delta \hat{U}_{mpc}^T H_{qp} \Delta \hat{U}_{mpc} +$$

$$+ 2 \left\{ \begin{bmatrix} x^T(k) & u_{mpc}^T(k-1) \end{bmatrix} \begin{bmatrix} F_y^T \\ F_u^T P_y^T \end{bmatrix} Q P_y P_u + \begin{bmatrix} x^T(k) & u_{mpc}^T(k-1) \end{bmatrix} \begin{bmatrix} 0_{nx,nu} \\ F_u^T \end{bmatrix} F_u^T \bar{R} P_u \right\} \Delta \hat{U}_{mpc} + cte$$

$$J = \Delta \hat{U}_{mpc}^T H_{qp} \Delta \hat{U}_{mpc} +$$

$$+ \begin{bmatrix} x^T(k) & u_{mpc}^T(k-1) \end{bmatrix} \cdot \underbrace{2 \left(\begin{bmatrix} F_y^T \\ F_u^T P_y^T \end{bmatrix} Q P_y P_u + \begin{bmatrix} 0_{nx,nu} \\ F_u^T \end{bmatrix} F_u^T \bar{R} P_u \right)}_{F_{qp}} \Delta \hat{U}_{mpc} + cte$$

$$\bar{J} = \Delta\hat{U}_{mpc}^T H_{qp} \Delta\hat{U}_{mpc} + \left[x^T(k) \; \hat{U}^T_{mpc}(k-1) \right] f_{qp} \; \Delta\hat{U}_{mpc} + cte$$ (03)

Sendo

$$H_{qp} = P_u^T P_y^T Q P_y P_u + R + P_u^T \bar{R} P_u$$

$$f_{qp} = 2\left(\begin{bmatrix} f_y^T \\ f_u^T P_y^T \end{bmatrix} Q P_y P_u + \begin{bmatrix} 0_{nx,nu} \\ f_u^T \end{bmatrix} f_u^T \bar{R} P_u \right.$$

Importante

$$\bar{R} = \begin{bmatrix} \bar{r} & & & 0 \\ & \bar{r} & & \\ & & \bar{r} & \\ 0 & & & \bar{r} \end{bmatrix}, \quad \bar{r} \in \mathbb{R}^{nu,nu}$$

peso dos controles totais

adotar

$$\bar{r} = [\alpha_1 \quad \alpha_2 \quad 0]$$

peso dos tilts

peso do incremento que é somado a ambos motores. Deve ser nulo