$$x(k+1) = Ax(k) + B_u u(k) + B_d u_d(k)$$
$$y(k) = Cx(k)$$

$$x(k) = Ax(k|k) + B_u u(k) + B_d u_d(k)$$

$$\mathcal{X}(k) = \begin{bmatrix} x(k+1|k) \\ \vdots \\ x(k+H_p|k) \end{bmatrix} \quad \mathcal{A} = \begin{bmatrix} A \\ \vdots \\ A^{H_p} \end{bmatrix} \quad \mathcal{B}_u = \begin{bmatrix} B_u & 0 & \cdots & 0 \\ AB_u & B_u & \cdots & 0 \\ \vdots & & \ddots & \vdots \\ A^{H_p-1}B_u & A^{H_p-2}B_u & & B_u \end{bmatrix}$$

$$\mathcal{B}_d = \begin{bmatrix} B_d & 0 & \cdots & 0 \\ AB_d & B_d & \ddots & 0 \\ \vdots & & \ddots & \vdots \\ A^{H_p-1}B & A^{H_p-2}B & \cdots & B_d \end{bmatrix} \quad U(k) = \begin{bmatrix} u(k) \\ \vdots \\ u(k+H_p-1) \end{bmatrix} \quad U_d(k) = \begin{bmatrix} u(k) \\ \vdots \\ u(k+H_p-1) \end{bmatrix}$$

$$C = diag(C)$$

$$Y(k) = \begin{bmatrix} y(k+1) \\ \vdots \\ y(k+H_p-1) \end{bmatrix} = Cx(k+1) = C\mathcal{X}(k)$$

$$\Psi = C\mathcal{A} \quad \Upsilon = C\mathcal{B}_u \quad \Theta = C\mathcal{B}_d$$

$$Y(k) = \Psi x(k|k) + \Upsilon U(k) + \Theta U_d(k)$$

$$J = \sum_{i=0}^{H_p} \| y(k+i) + y(k+i-1) \|^2_{Q(i)}$$

S.T.
$$x(k+i+1) = Ax(k+i) + Bu(k+i) + B_d u_d(k+i)$$
$$y(k+i) = Cx(k+i)$$

$$J = \|\gamma(k) - \gamma(k-1)\|^2_{Q(i)} = (\gamma(k)^T - \gamma(k-1)^T) Q (\gamma(k) - \gamma(k-1))$$

$$\gamma(k)^T Q \gamma(k) + \gamma(k-1)^T Q \gamma(k-1) - \gamma(k)^T Q \gamma(k-1) - \gamma(k-1)^T Q \cdot \gamma(k)$$

$$\gamma(k)^T Q \gamma(k) = (x(k|k)^T \Psi(k)^T + u(k)^T \Upsilon(k)^T + u_d(k)^T \theta^T) Q (\Psi(k) x(k|k) + \Upsilon u(k) + \theta u_d(k))$$

$$= x(k|k)^T \Psi(k)^T Q \Psi x(k|k) + x(k|k)^T \Psi^T Q \Upsilon u(k) + x(k|k)^T \Psi^T Q \theta u_d(k) +$$

$$u(k)^T \Upsilon^T Q \Psi x(k|k) + \quad + \underline{u(k)^T \Upsilon^T Q \Upsilon u(k)} + u(k)^T \Upsilon^T Q \theta u_d(k) +$$

$$u_d(k)^T \theta^T Q \Psi x(k|k) + u_d(k)^T \theta^T Q \Upsilon u(k) + u_d(k)^T \theta^T Q \theta u_d(k)$$

$$\gamma(k-1)^T Q \gamma(k-1) =$$

$$= x(k-1|k)^T \Psi^T Q \Psi x(k-1|k) + x(k-1|k)^T \Psi^T Q \Upsilon u(k-1) + x(k-1|k)^T \Psi^T Q \theta u_d(k-1) +$$

$$u(k-1)^T \Upsilon^T Q \Psi x(k-1|k) + u(k-1)^T \Upsilon^T Q \Upsilon u(k-1) + u(k-1)^T \Upsilon^T Q \theta u_d(k-1) +$$

$$u_d(k-1)^T \theta^T Q \Psi x(k-1|k) + u_d(k-1)^T \theta^T Q \Upsilon u(k-1) + u_d(k-1)^T \theta^T Q \theta u_d(k-1)$$

$$- \gamma(k)^T Q \gamma(k-1) =$$

$$- (x(k|k)^T \Psi^T Q \Psi x(k-1|k) + x(k|k)^T \Psi^T Q \Upsilon u(k-1) + x(k|k)^T \Psi^T Q \theta u_d(k-1) +$$

$$\underline{u(k)^T \Upsilon^T Q \Psi x(k-1|k)} + \underline{u(k)^T \Upsilon^T Q \Upsilon u(k-1)} + \underline{u(k)^T \Upsilon^T Q \theta u_d(k-1)} +$$

$$u_d(k)^T \theta^T Q \Psi x(k-1|k) + u_d(k)^T \theta^T Q \Upsilon u(k-1) + u_d(k)^T \theta^T Q \theta u_d(k-1))$$

$$- \gamma(k-1)^T Q \gamma(k) =$$

$$- (x(k-1|k)^T \Psi^T Q \Psi x(k|k) + \underline{x(k-1|k)^T \Psi^T Q \Upsilon u(k)} + x(k-1|k)^T \Psi^T Q \theta u_d(k) +$$

$$u(k-1)^T \Upsilon^T Q \Psi x(k|k) + \underline{u(k-1)^T \Upsilon^T Q \Upsilon u(k)} + u(k-1)^T \Upsilon^T Q \theta u_d(k) +$$

$$u_d(k-1)^T \theta^T Q \Psi x(k|k) + \underline{u_d(k-1)^T \theta^T Q \Upsilon u(k)} + u_d(k-1)^T \theta^T Q \theta u_d(k)$$

Constant   Linear   Quadric

$$H = \Upsilon^T Q \Upsilon$$

$$f = \left[2(x(k|k)^T \Psi^T Q \Upsilon u(k) + 2(u_d^T \Theta^T Q \Upsilon u(k)) - \right.$$

$$\left(2(x(k-1|k)^T \Psi^T Q \Upsilon u(k)) \right) - \left(2(u(k-1)^T \Upsilon^T Q \Upsilon u(k)) \right)$$

$$- \left(2(u_d(k-1)^T \Theta^T Q \Upsilon u(k)) \right)$$

$$\min_u J = \min_u \; u^T H u + f u + c$$

$$c = \text{constant}$$

$$x(k|k)^{263 \times 1} \qquad \Psi^{10 \times 263} \qquad \Upsilon^{10 \times 120} \qquad \Theta^{10 \times 120} \qquad Q^{10 \times 10}$$

$$u(k-1)^{1 \times 12}$$