
*

$$\begin{pmatrix} - & - \\ - & - \\ - & - \\ - & - \\ - & - \end{pmatrix}$$

LQR

- LQR - - :

(SMC)

(LQR)

(MPC)

$$H_2 \quad H_\infty \quad []$$

[-] (LQR)
(MPC)

(SMC)

[-]

[-]

()

:[]

$$\dot{Z}(t) = A Z(t) + B u(t)$$

q

()

LQR

J

LQR

:

$$J = \int_0^{\infty} [Z^T(t) Q Z(t) + u^T(t) R u(t) + 2Z^T(t)^T N u(t)] dt$$

()

N R Q

R Q

J

J

G

u(t)

:

$$u(t) = -\frac{1}{2} R^{-1} (B^T P + N^T) Z(t) = -G Z(t)$$

$$= -\begin{bmatrix} G_x & G_{\dot{x}} \end{bmatrix} \begin{bmatrix} x(t) \\ \dot{x}(t) \end{bmatrix}$$

()

dx ()

:[]

$$\int_{x(0)}^{x(t_k)} \ddot{x}(t)^T M dx + \int_{x(0)}^{x(t_k)} \dot{x}(t)^T C dx + \int_{x(0)}^{x(t_k)} x(t)^T K dx$$

$$= -\int_{x(0)}^{x(t_k)} E^T M \ddot{x}_g(t) dx + \int_{x(0)}^{x(t_k)} u(t)^T D^T dx$$

()

P

G

:

$$A^T P + P A - (P B + N) R^{-1} (B^T P + N^T) + Q = 0$$

()

:

+

+

=

Q

R

$$dx = \dot{x}(t) dt$$

:

:

()

[-] R Q

[] R Q

•

•

•

$$\int_{t=0}^{t=t_k} \ddot{x}(t)^T M \dot{x}(t) dt +$$

$$\int_{t=0}^{t=t_k} \dot{x}(t)^T C \dot{x}(t) dt + \int_{t=0}^{t=t_k} x(t)^T K \dot{x}(t) dt$$

()

[]

Z

$$Q = q \begin{bmatrix} K & 0 \\ 0 & M \end{bmatrix}$$

$$R = I, N = 0$$

()

$$= \int_{t=0}^{t=t_k} \left(\frac{d}{dt} Z^T(t) \right) Q^* Z(t) dt$$

R

Q

q

()

$$N^* = D_{n \times m} \begin{bmatrix} I & 0 \end{bmatrix}_{m \times 2n} \quad ()$$

$$Q^* = \begin{bmatrix} K & C \\ 0 & M \end{bmatrix}$$

$t_{k+1} \quad t_k$

()

$$= \frac{1}{2} Z^T(t) \hat{Q} Z(t) \Big|_{t_k}^{t_{k+1}} + u(t)^T N^* Z(t) \Big|_{t_k}^{t_{k+1}} \quad ()$$

$$\int \left(\frac{d}{dt} Z^T(t) \right) Q^* Z(t) dt = Z^T(t) Q^* Z(t) - \int Z^T(t) Q^* \left(\frac{d}{dt} Z(t) \right) dt \quad ()$$

$$J = \int_{t=0}^{\infty} (Z^T(t) Q Z(t) + 2u(t)^T N Z(t)) dt$$

$$Q = \frac{1}{2} \begin{bmatrix} K & C \\ C & M \end{bmatrix} \quad N = \frac{1}{2} D_{n \times m} \begin{bmatrix} I & 0 \end{bmatrix}_{m \times 2n} \quad ()$$

$$= \int \left(\frac{d}{dt} Z^T(t) \right) Q^* Z(t) dt = \frac{1}{2} Z^T(t) Q^* Z(t) \quad ()$$

LQR () ()

R ()

LQR () ()

()

$$= \frac{1}{2} Z^T(t) \hat{Q} Z(t) \quad ()$$

R ()

()

$$\hat{Q} = \begin{bmatrix} K & C \\ C & M \end{bmatrix} \quad ()$$

$$J = \lim_{R \rightarrow 0} \int_0^{\infty} [Z^T(t) Q Z(t) + u^T(t) R u(t) + 2Z^T(t)^T N u(t)] dt \quad ()$$

$$\bar{Z}(t) = G Z(t) + H u(t) \quad ()$$

$$- \int u(t)^T D^T D x = - \int u(t)^T D^T \dot{x}(t) dt \quad ()$$

$$J = \int_0^{\infty} [\bar{Z}^T(t) \bar{Q} \bar{Z}(t) + u^T(t) \bar{R} u(t)] dt \quad ()$$

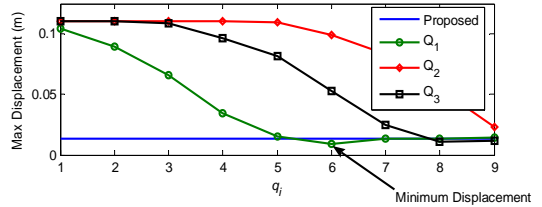
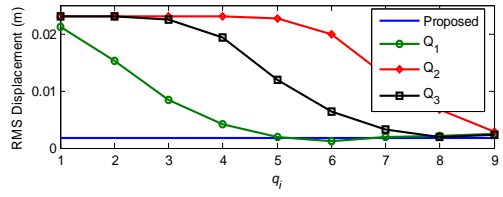
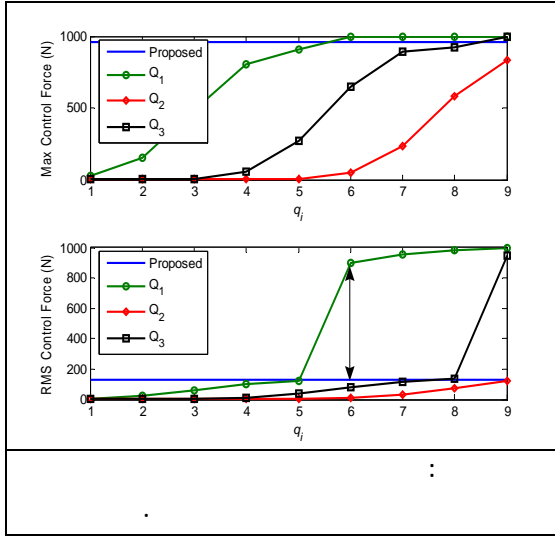
$$Q = G^T \bar{Q} G$$

$$R = H^T \bar{Q} H + \bar{R}$$

$$N = G^T \bar{Q} H \quad ()$$

$$= -u(t)^T D x(t) \Big|_{t_k}^{t_{k+1}} = -u(t)^T N^* Z(t) \Big|_{t_k}^{t_{k+1}} \quad ()$$

()
 $(q_i=6)$ Q_1



()

() q_i

$(q_i=6)$ LQR Q_1

()

()

$(q_i=6)$ Q_1

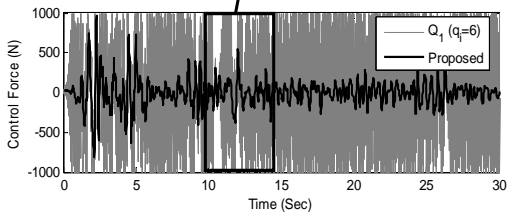
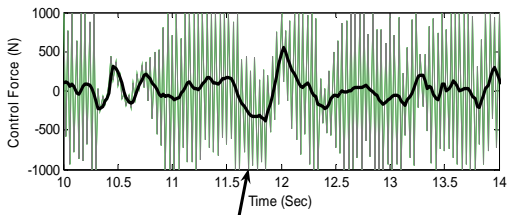
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$(q_i=6)$ Q_1

$(q_i=6)$ Q_1



Q_1

$(q_i=6)$

$(q_i=6)$ Q_1

$(q_i=6)$ Q_1

Q_1

Q_1 $(q_i=6)$

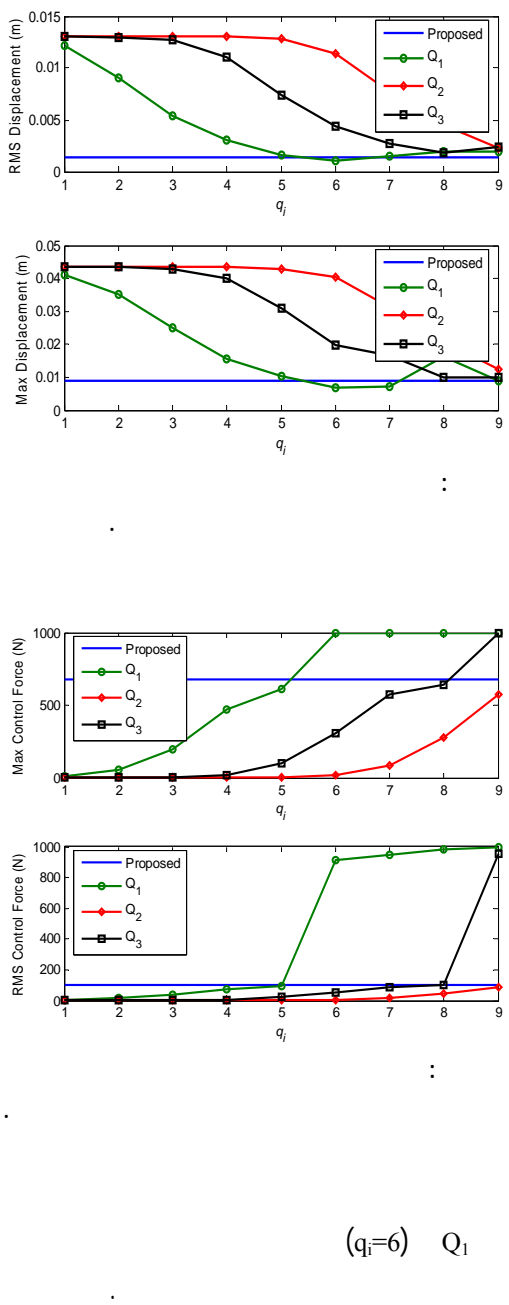
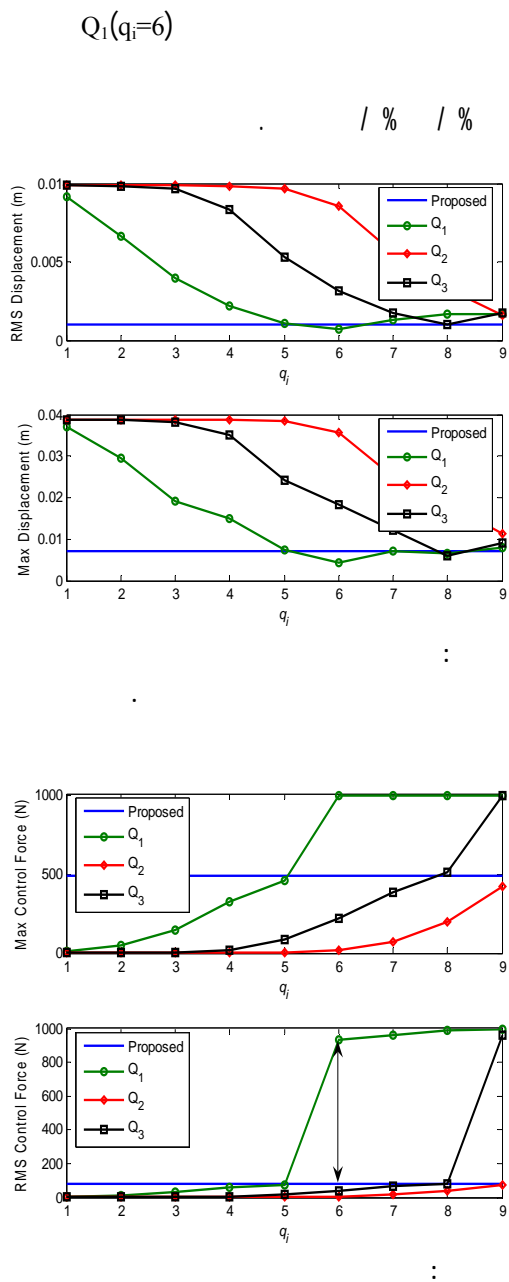
$(q_i \geq 6)$

(-)

Q_1

$(q_i=6)$ Q_1

$(q_i=5)$



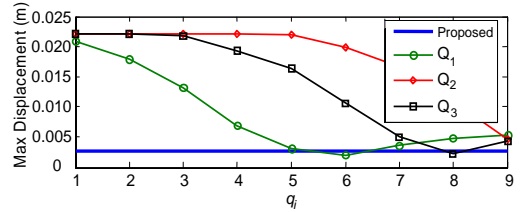
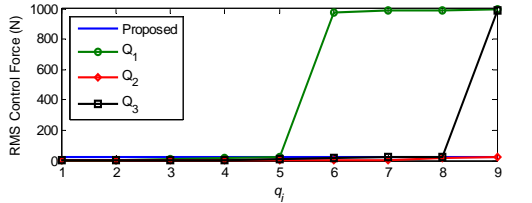
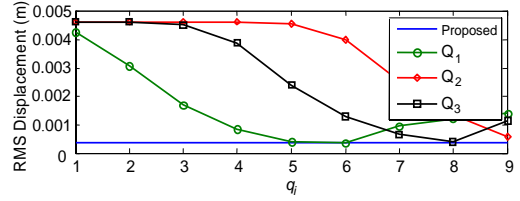
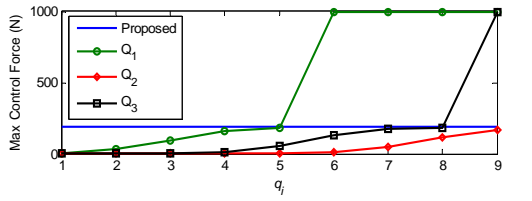
$(q_i=6) Q_1$

Bang-Bang

()

$Q_1(q_i=6)$

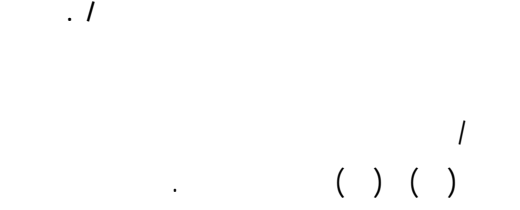
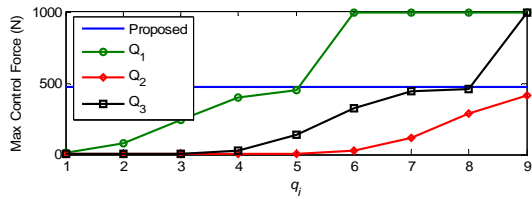
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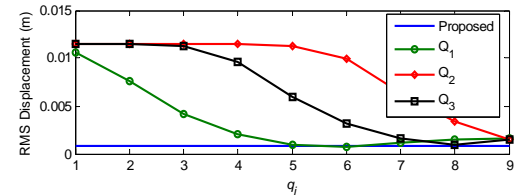
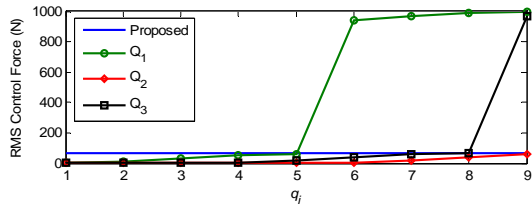
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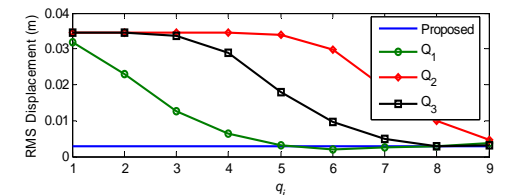
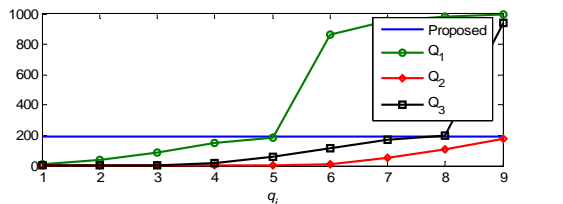
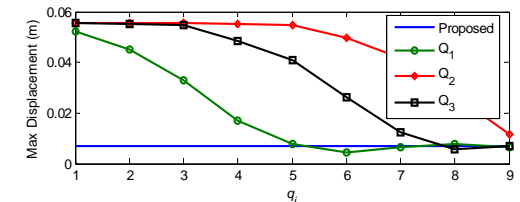
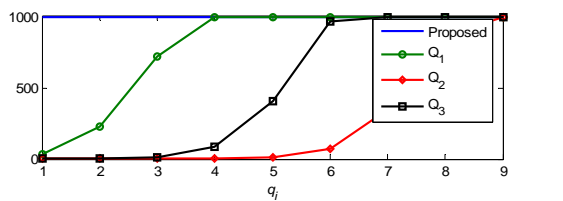
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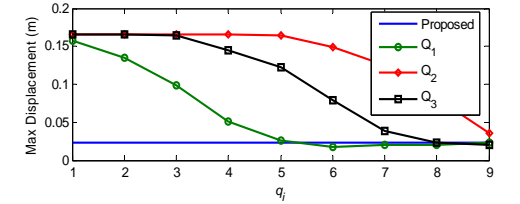
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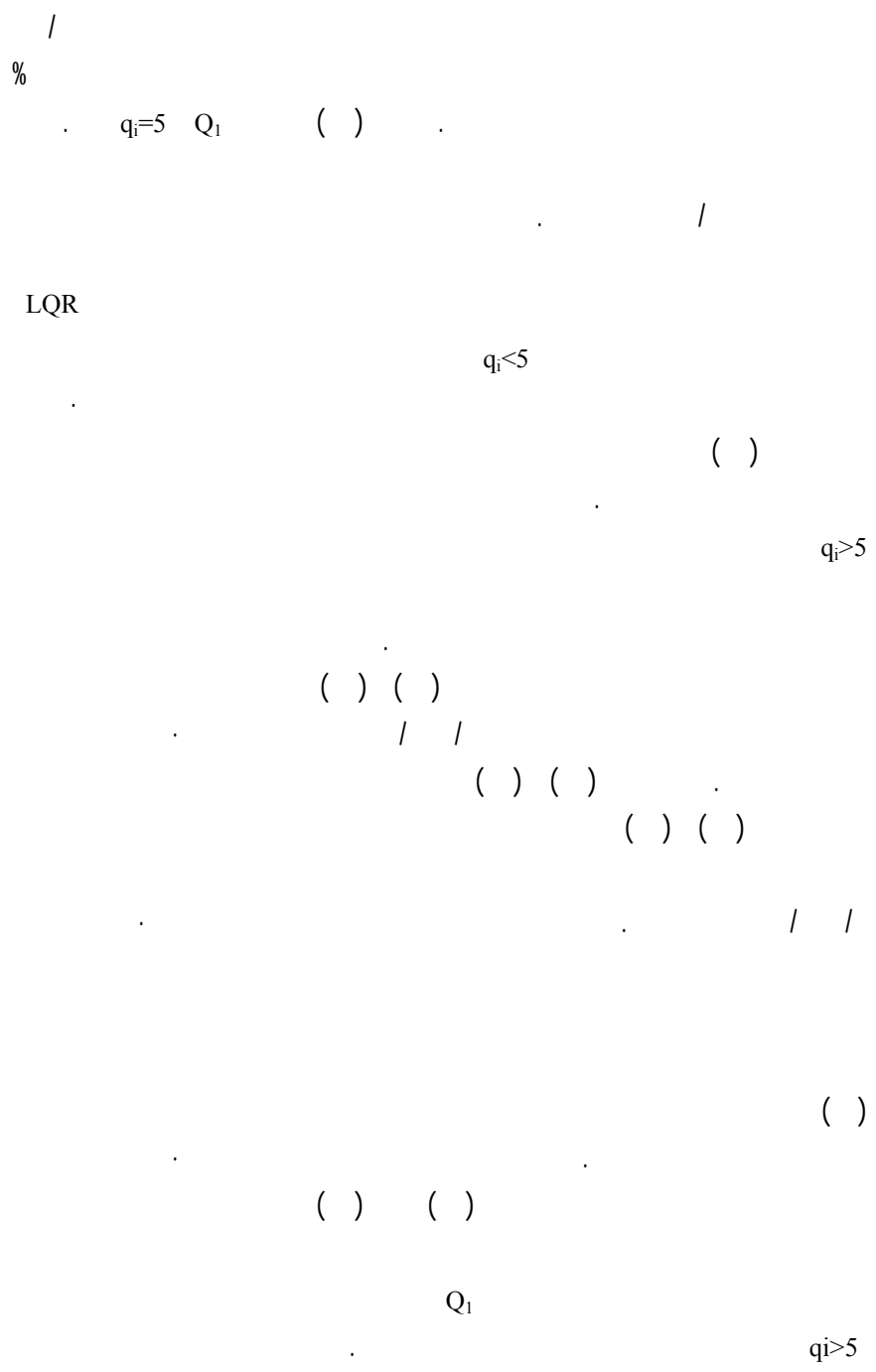
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- 1 - On Line
 - 2 - Sliding Mode Control
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