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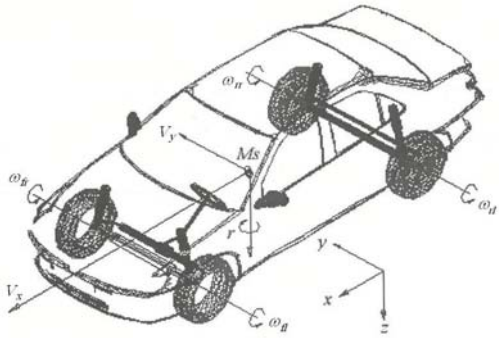
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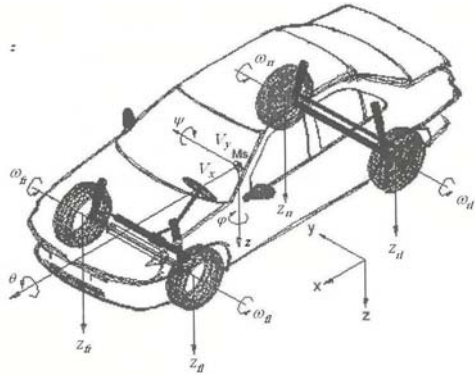
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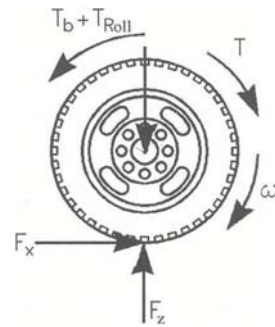
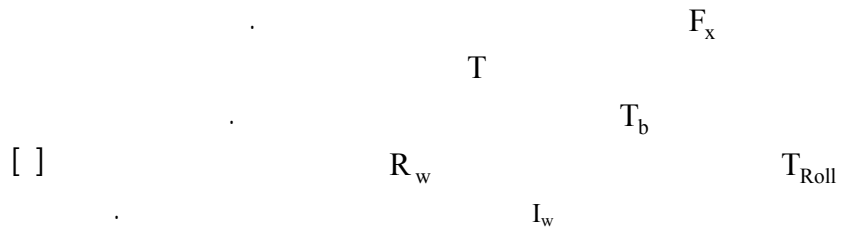
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McPherson

Multi Link

$$I_w \dot{\omega} = -F_x \cdot R_w + T - T_b - T_{Roll} \quad (1)$$



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$$T_{Roll} = f_r \cdot F_z \cdot R_w \quad (2)$$

$$r_{des} = \frac{u \delta}{L(1 + Ku^2)}$$

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$$\frac{u}{K} \quad \frac{r_{des}}{\delta} \quad L$$

$$[ ] \quad / \quad / \quad f_r$$

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$$\lambda = \frac{V_r - V_x}{V_x}$$

$$V_r = R\omega$$

$V_x$

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$$e = r - r_{des}$$

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$$\varepsilon = K_I \int_0^t e dt + K_P e + K_D \frac{de}{dt}$$

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$$r_{des} \geq 0$$

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$$r_{des} < 0$$

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$$\lambda_0 = -0.125$$

$$\dot{\lambda} = g + u_b$$

$$g = -\frac{\dot{v}_x}{v_x}(1 + \lambda) - \frac{R^2 F_x}{v_x I_w}$$

$$u_b = -\frac{R}{v_x I_w} T_b$$

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$F_x$

$\dot{v}_x$

$$\lambda_{dfr} = \begin{cases} \lambda_0 + \varepsilon & r \geq 0 \ \& \ \varepsilon \geq 0 \\ \lambda_0 - \varepsilon & r \geq 0 \ \& \ \varepsilon \leq 0 \\ \lambda_0 - \varepsilon & r \leq 0 \ \& \ \varepsilon \geq 0 \\ \lambda_0 & \text{else} \end{cases}$$

$$\lambda_{dfl} = \begin{cases} \lambda_0 - \varepsilon & r \geq 0 \ \& \ \varepsilon \geq 0 \\ \lambda_0 + \varepsilon & r \geq 0 \ \& \ \varepsilon \leq 0 \\ \lambda_0 + \varepsilon & r \leq 0 \ \& \ \varepsilon \geq 0 \\ \lambda_0 & \text{else} \end{cases}$$

$$\lambda_{fr} = \lambda_{fr}$$

$$\lambda_{fl} = \lambda_{fl}$$

$$|g - \hat{g}| \leq G$$

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$$s = \lambda - \lambda_d$$

(n=1)

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$$\lambda_{dfr} = \begin{cases} \lambda_0 - \varepsilon & r \leq 0 \ \& \ \varepsilon \geq 0 \\ \lambda_0 + \varepsilon & r \leq 0 \ \& \ \varepsilon \leq 0 \\ \lambda_0 + \varepsilon & r \geq 0 \ \& \ \varepsilon \geq 0 \\ \lambda_0 & \text{else} \end{cases}$$

$$\lambda_{dfl} = \begin{cases} \lambda_0 + \varepsilon & r \leq 0 \ \& \ \varepsilon \geq 0 \\ \lambda_0 - \varepsilon & r \leq 0 \ \& \ \varepsilon \leq 0 \\ \lambda_0 - \varepsilon & r \geq 0 \ \& \ \varepsilon \geq 0 \\ \lambda_0 & \text{else} \end{cases}$$

$$\lambda_{fr} = \lambda_{fr}$$

$$\lambda_{fl} = \lambda_{fl}$$

$$\frac{d}{dt} s = \dot{s} = 0$$

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$$\text{sat}\left(\frac{s}{\phi}\right) = \begin{cases} 1 & s > \phi \\ \frac{s}{\phi} & |s| \leq \phi \\ -1 & s < -\phi \end{cases}$$

sgn(s)

$$\dot{\lambda} = 0 \quad ( ) \quad ( )$$

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$$\hat{u}_{b,eq} = -\hat{g}$$

$$\hat{g} = -\frac{\hat{v}_x}{v_x}(1 + \lambda) - \frac{R^2 \hat{F}_x}{v_x I_w} \quad ( )$$

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$$u_b = \hat{u}_{b,eq} - k \text{sign}(s) \quad ( )$$

k

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$$\frac{1}{2} \frac{d}{dt} s^2 \leq -\eta |s| \quad ( )$$

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$$\begin{aligned} \frac{1}{2} \frac{d}{dt} s^2 &= \dot{s} \cdot s = [g + u_b]s \\ &= [g + \hat{u}_{b,eq} - k \text{sign}(s)]s \\ &= [g - \hat{g} - k \text{sign}(s)]s \\ &= (g - \hat{g})s - k \text{sign}(s)s \\ &= (g - \hat{g})s - k|s| \end{aligned} \quad ( )$$

k

$$k = G + \eta \quad ( )$$

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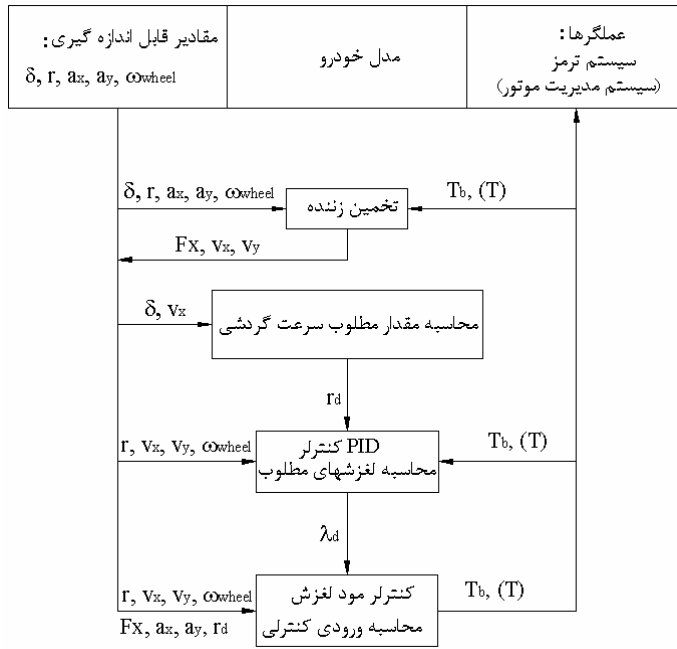
$$\begin{aligned} (g - \hat{g})s - k|s| &= (g - \hat{g})s - (G + \eta)|s| \\ &= (g - \hat{g})s - G|s| - \eta|s| \\ &\leq -\eta|s| \end{aligned} \quad ( )$$

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k

$$a_x = \frac{1}{m} [(F_{xfl} + F_{xfr}) \text{Cos}(\delta) - (F_{yfl} + F_{yfr}) \text{Sin}(\delta) + F_{xrr} + F_{xrl}] \quad ( )$$

$$a_y = \frac{1}{m} [(F_{xfl} + F_{xfr}) \text{Sin}(\delta) + (F_{yfl} + F_{yfr}) \text{Cos}(\delta) + F_{yrr} + F_{yrl}] \quad ( )$$



$$a_y = \frac{1}{m} [(F_{xfl} + F_{xfr}) \sin(\delta) + F_{yfl} \cos(\delta) + F_{yrl}]$$

$$\dot{r} = \frac{1}{I_{zz}} [(F_{xfl} + F_{xfr}) L_f \sin(\delta) + (F_{yfl} + F_{yfr}) L_f \cos(\delta) - (F_{yrl} + F_{yrr}) L_r + (F_{xfr} - F_{xfl}) \frac{T_f}{2} \cos(\delta) + (F_{yfl} - F_{yfr}) \frac{T_f}{2} \sin(\delta) + (F_{xrr} - F_{xrl}) \frac{T_r}{2}]$$

$$\dot{r} = \frac{1}{I_{zz}} [(F_{xfl} + F_{xfr}) L_f \sin(\delta) + F_{yfl} L_f \cos(\delta) - F_{yrl} L_r + (F_{xfr} - F_{xfl}) \frac{T_f}{2} \cos(\delta) + (F_{xrr} - F_{xrl}) \frac{T_r}{2}]$$

$$\dot{\omega}_{fl} = \frac{(T_{fl} - R_w F_{xfl})}{I_w} \quad \dot{\omega}_{fr} = \frac{(T_{fr} - R_w F_{xfr})}{I_w}$$

$$\dot{\omega}_{rl} = \frac{(T_{rl} - R_w F_{xrl})}{I_w} \quad \dot{\omega}_{rr} = \frac{(T_{rr} - R_w F_{xrr})}{I_w}$$

$$y(t) = W(t)a(t)$$

$$y(t) = \begin{bmatrix} \delta = 0 \\ F_{yrr} + F_{yrl} \\ F_{yfr} + F_{yfl} \end{bmatrix}$$

$$y(t) = \begin{bmatrix} a_x & a_y & \dot{r} & \dot{\omega}_{fr} - \frac{T_{fr}}{I_w} \\ \dot{\omega}_{fl} - \frac{T_{fl}}{I_w} & \dot{\omega}_{rr} - \frac{T_{rr}}{I_w} & \dot{\omega}_{rl} - \frac{T_{rl}}{I_w} \end{bmatrix}^T$$

$$a_x = \frac{1}{m} [(F_{xfl} + F_{xfr}) \cos(\delta) - F_{yfl} \sin(\delta) + F_{xrr} + F_{xrl}]$$

a(t)

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Parameter	Content	Unit
$M_s$	1270	Kg
$M_{uf}$	95.5	Kg
$M_{ur}$	108.8	Kg
$I_x$	346.73	$Kgm^2$
$I_y$	1675.8	$Kgm^2$
$I_z$	1808.8	$Kgm^2$
$T_f$	1.4375	m
$T_r$	1.4375	m
$L_f$	1.2247	m
$L_r$	1.4373	m
$R_w$	0.285	m
$I_w$	1.4	$Kgm^2$
$K_f$	15400	N/m
$K_r$	19000	N/m
$C_f$	1150	N.s/m
$C_r$	6000	N.s/m

$$a(t) = [F_{xfr} \quad F_{xfl} \quad F_{xrr} \quad F_{xrl} \quad F_{yf} \quad F_{yr}]^T \quad ( )$$

$$W(t) = \begin{bmatrix} \frac{\cos \delta}{m} & \frac{\cos \delta}{m} & \frac{1}{m} & \frac{1}{m} & \frac{\sin \delta}{m} & 0 \\ \frac{\sin \delta}{m} & \frac{\sin \delta}{m} & 0 & 0 & \frac{\cos \delta}{m} & \frac{1}{m} \\ L_f \sin \delta - \frac{T_f}{2} \cos \delta & L_r \sin \delta + \frac{T_r}{2} \cos \delta & -\frac{T_f}{2I_z} & \frac{T_r}{2I_z} & \frac{L_f \cos \delta}{I_z} & -\frac{L_r}{I_z} \\ -\frac{R_w}{I_w} & 0 & 0 & 0 & 0 & 0 \\ 0 & -\frac{R_w}{I_w} & 0 & 0 & 0 & 0 \\ 0 & 0 & -\frac{R_w}{I_w} & 0 & 0 & 0 \\ 0 & 0 & 0 & -\frac{R_w}{I_w} & 0 & 0 \end{bmatrix}$$

$$a_x = \dot{v}_x - rv_y \quad ( )$$

$$a_y = \dot{v}_y + rv_x \quad ( )$$

m/s

$v_y \quad v_x$

$$\frac{d}{dt} \begin{bmatrix} \hat{v}_x \\ \hat{v}_y \end{bmatrix} = \begin{bmatrix} 0 & r_m \\ -r_m & 0 \end{bmatrix} \begin{bmatrix} \hat{v}_x \\ \hat{v}_y \end{bmatrix} + \begin{bmatrix} a_{xm} \\ a_{ym} \end{bmatrix} \quad ( )$$

$r_m \quad a_{ym} \quad a_{xm}$

$\hat{v}_y \quad \hat{v}_x$

m/s

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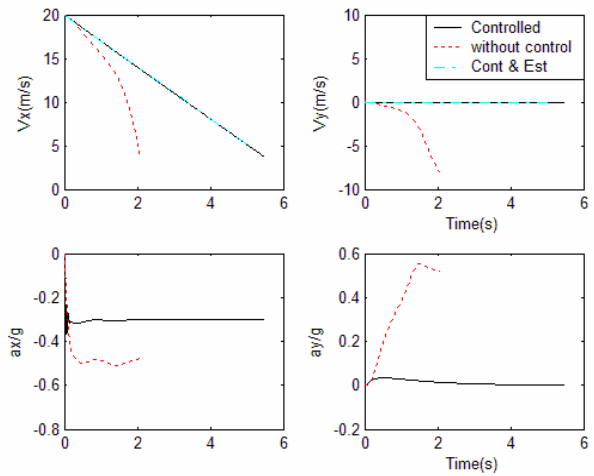
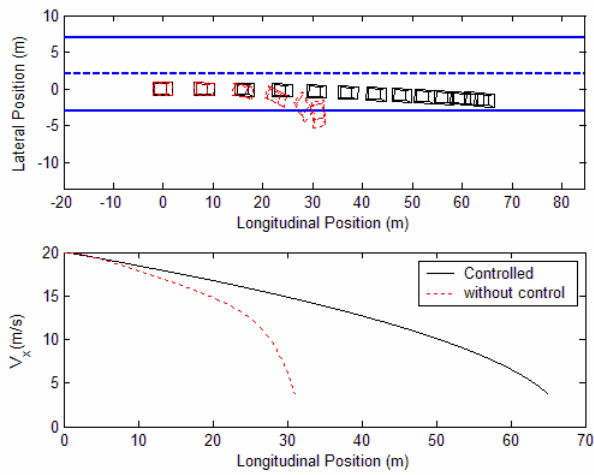
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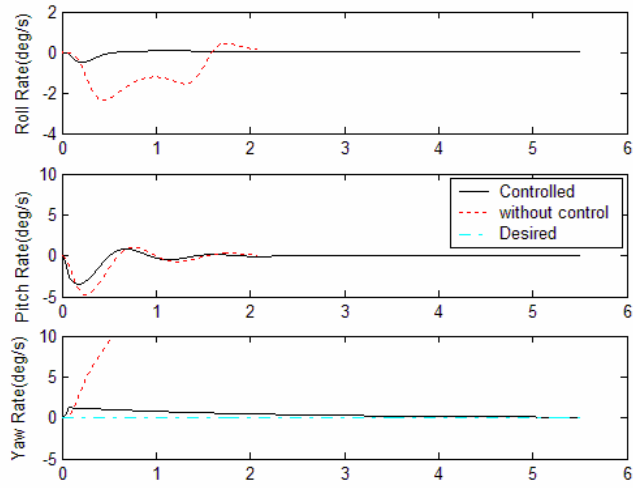
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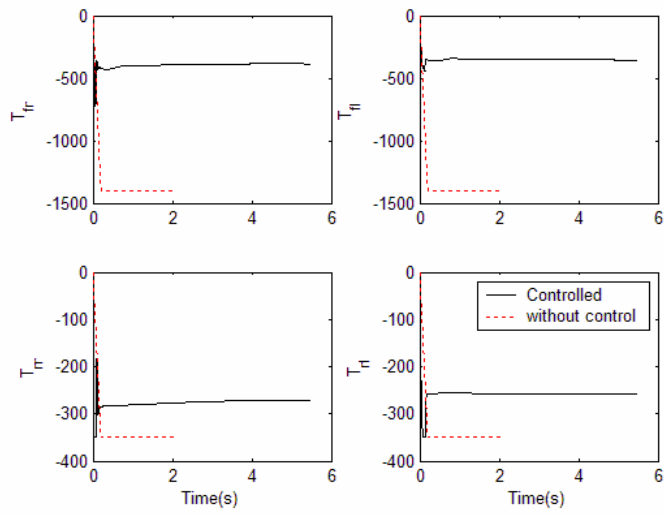
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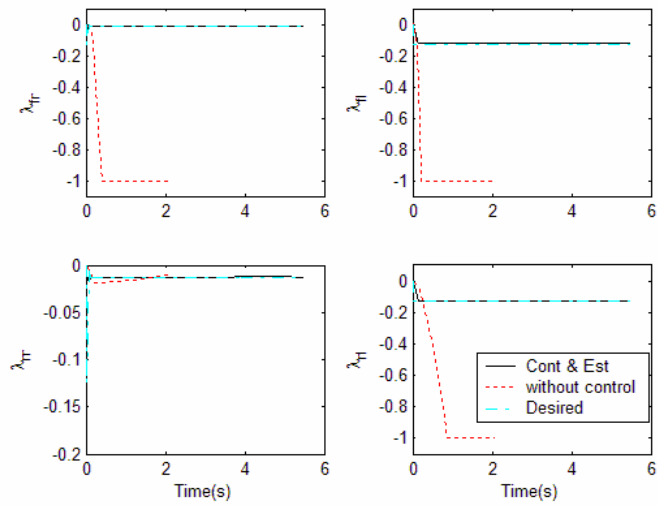




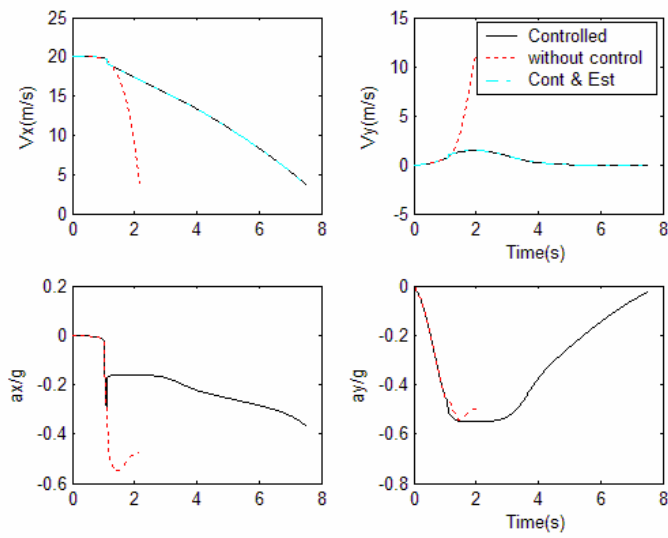
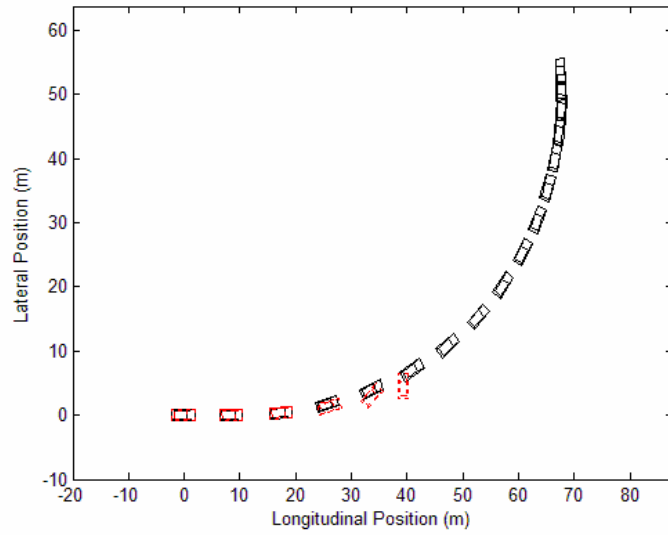
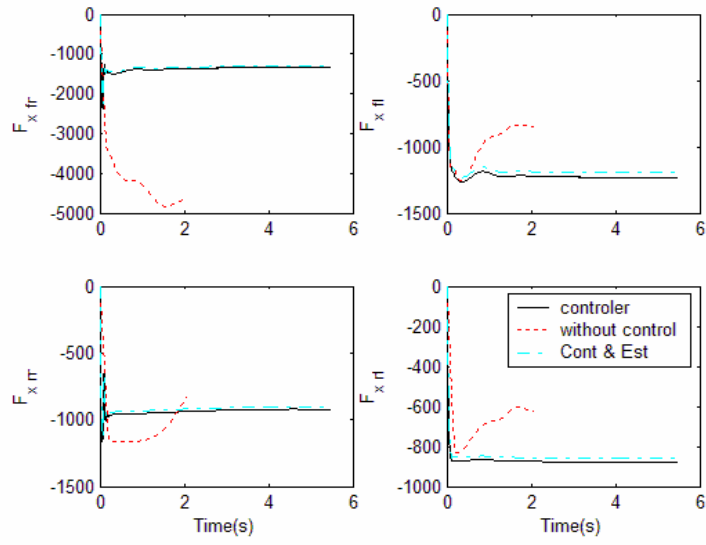
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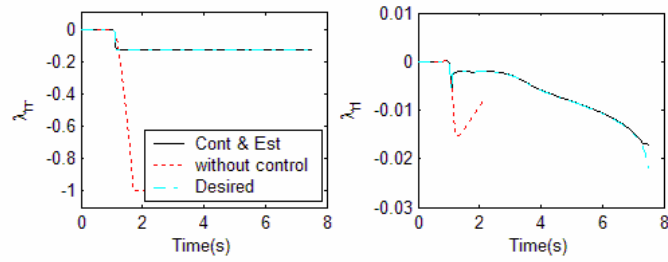
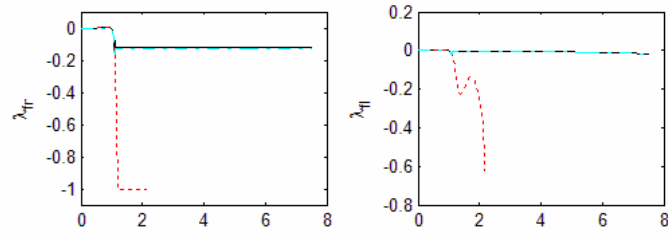
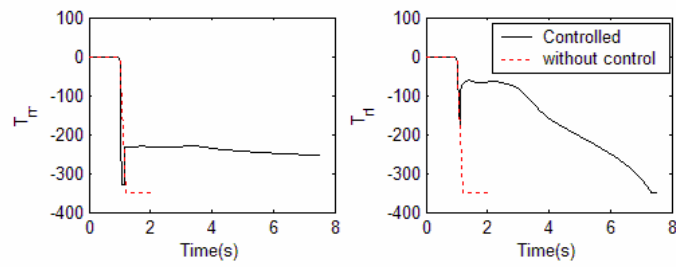
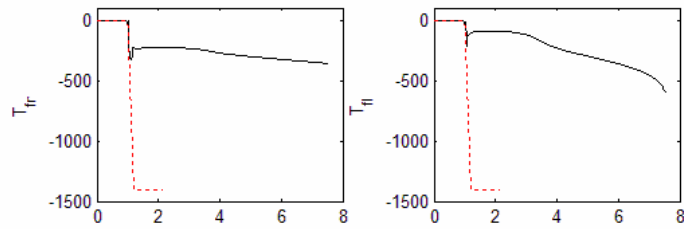
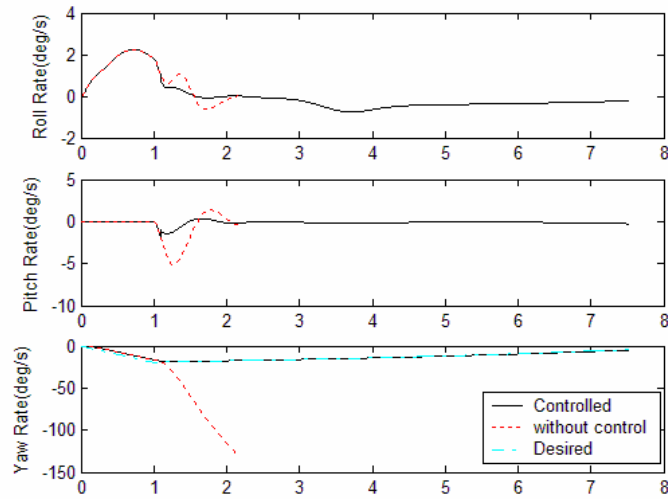


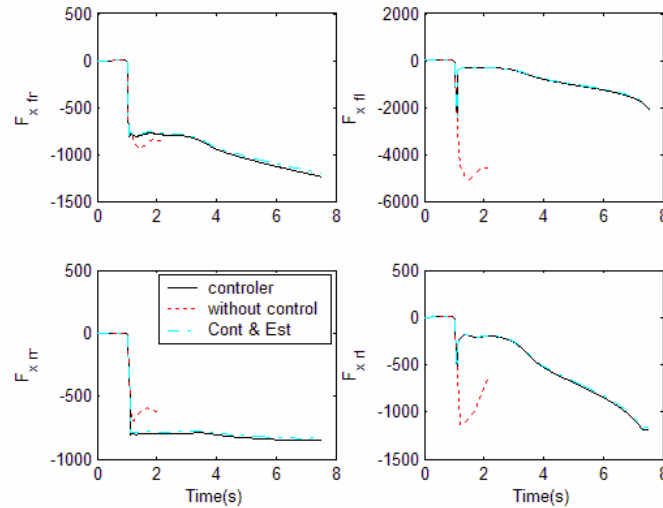
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1 - Anti Lock Brake System

2 - Wheel Slip

3 - Sliding Mode Control

4 - Least Squares with Exponential Forgetting

5 - Longitudinal

6 - Lateral

7 -Yaw

8 - Rolling Resistance

9 - Spilit