JOURNEE GT6 : PROTOTYPES ROBOTS TOUT-TERRAIN

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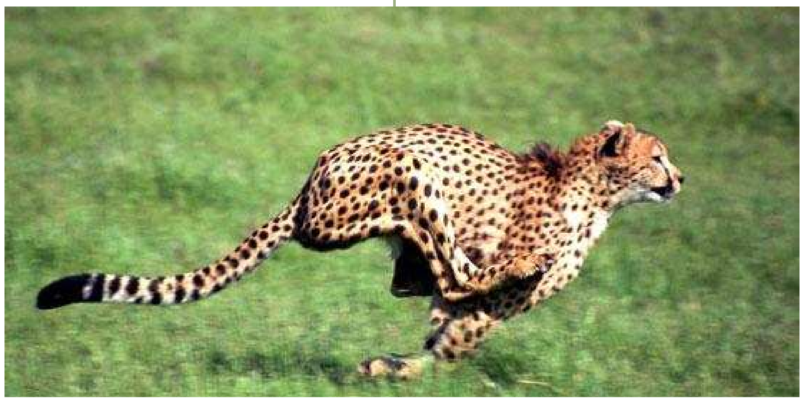
Robots à haute mobilité : agile et/ou rapide

Robots reconfigurables




Robot s rapides





Design and control of an anti-roll system for a fast off-road rover

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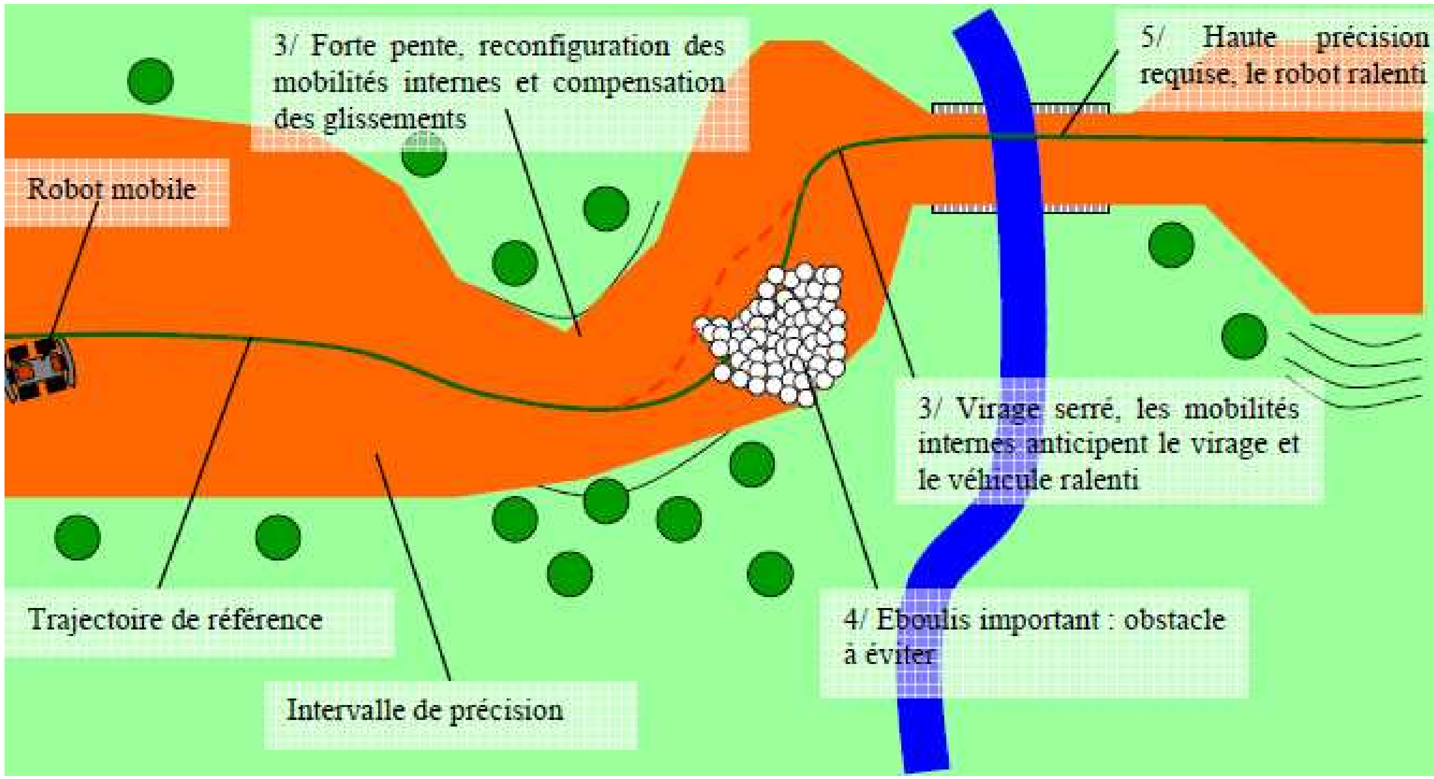
Context

National project FAST :

- *fast autonomous robot (10m/s) tracking a path defined by GPS-points*
- *agile robot (stabilisation system)*



RobuFast-A

8m/s : Suivi cinématique

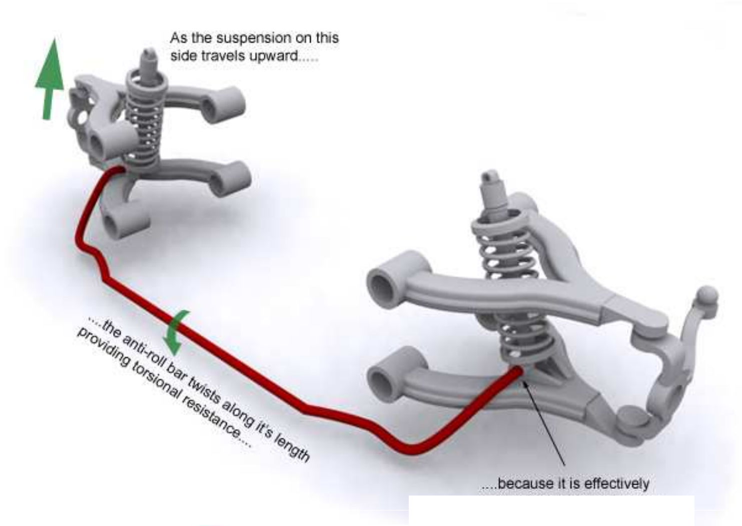
8m/s : Suivi cinématique avec stabilisation du lacet

Issues in off-road fast locomotion

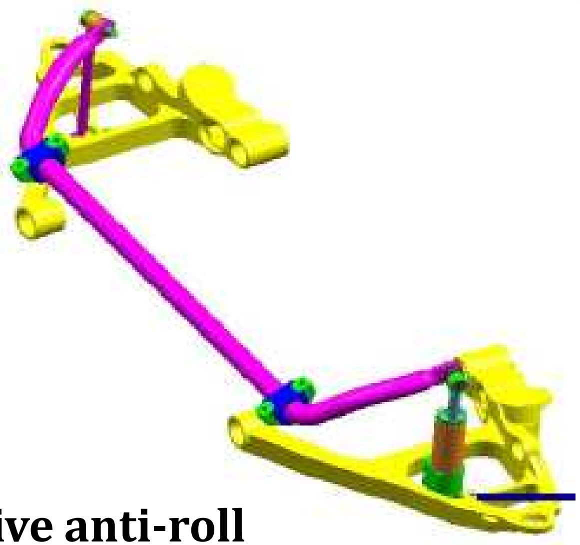
- Large displacement suspension
- High center of gravity
- Propensity to roll
- Risk of tip-over

Design of stabilization active system
- Avoiding lateral tip-over
- In the roll plane

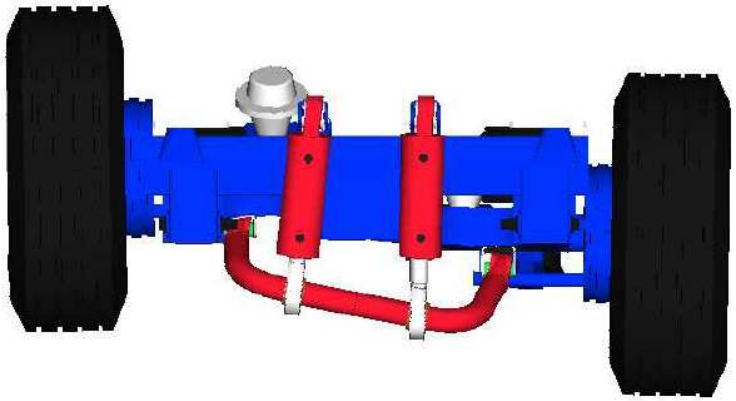
Active and passive anti-roll bar



Passive anti-roll bar



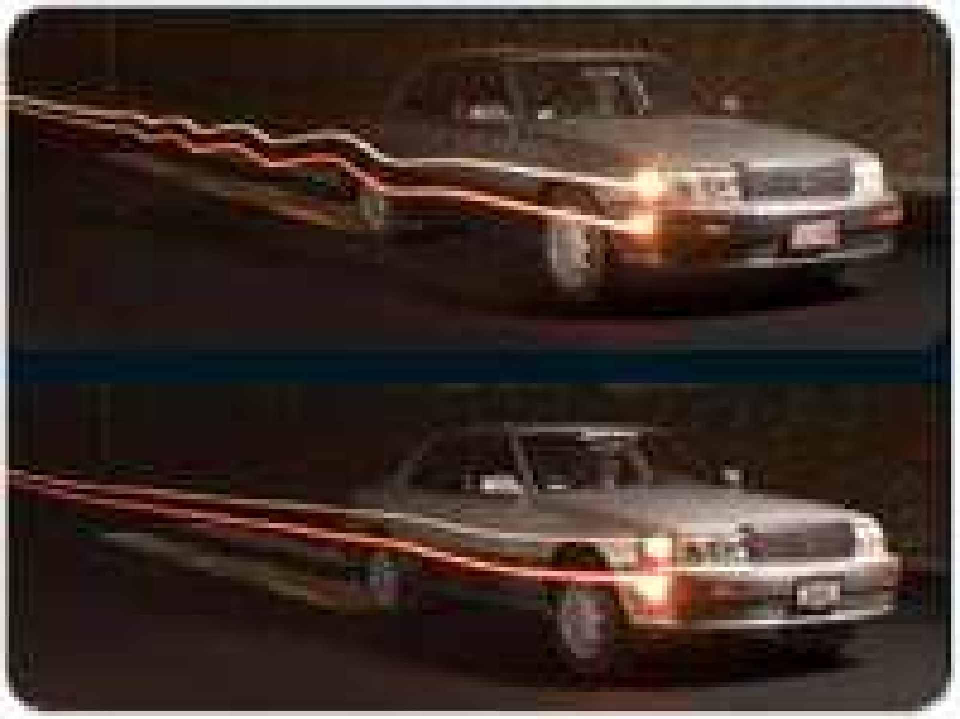
Active anti-roll bar for car [TRW]



Active anti-roll bar for heavy truck [Miege2004]

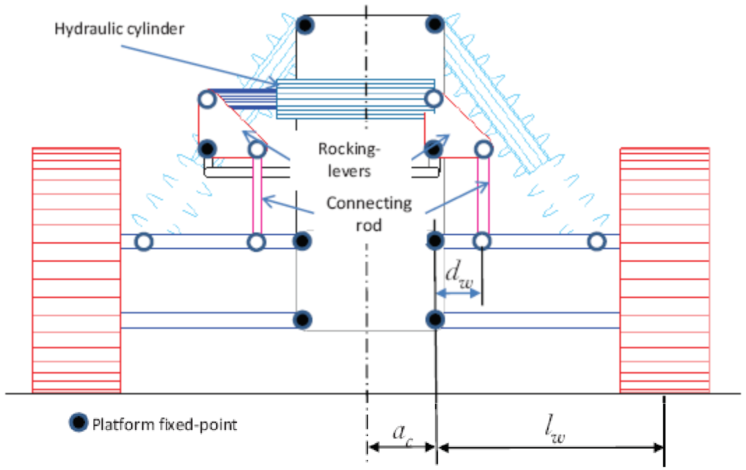
Active suspension

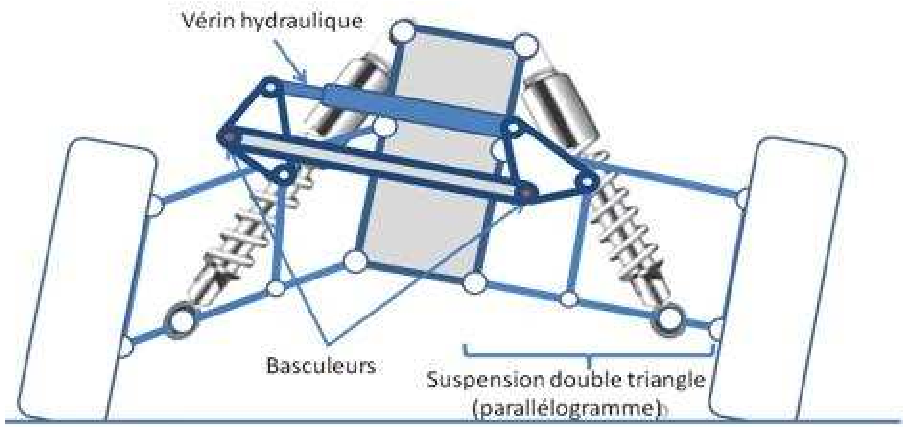
Electromagnetic
actuator [Bose TM]

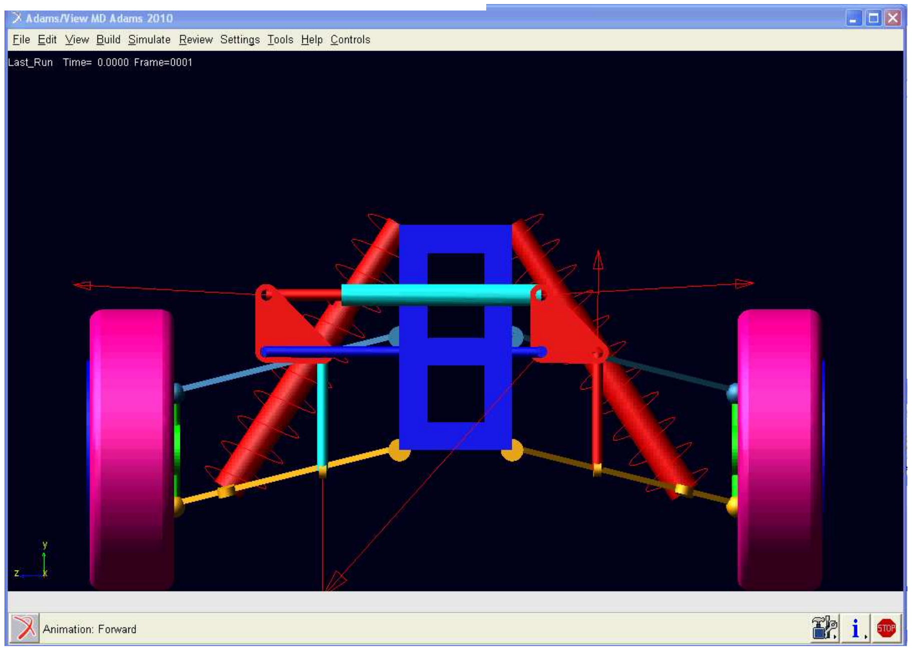


Proposed kinematics

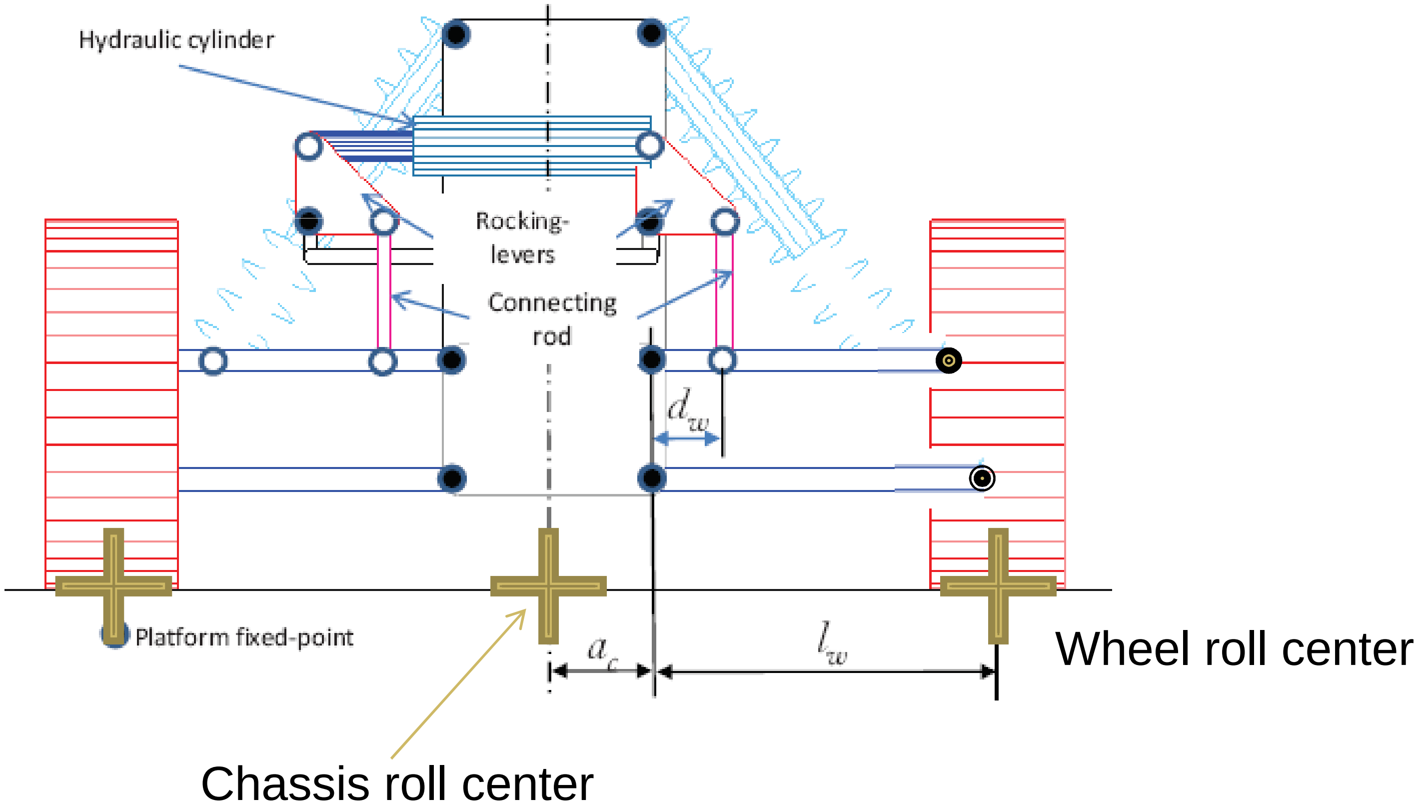
Integration on existant chassis





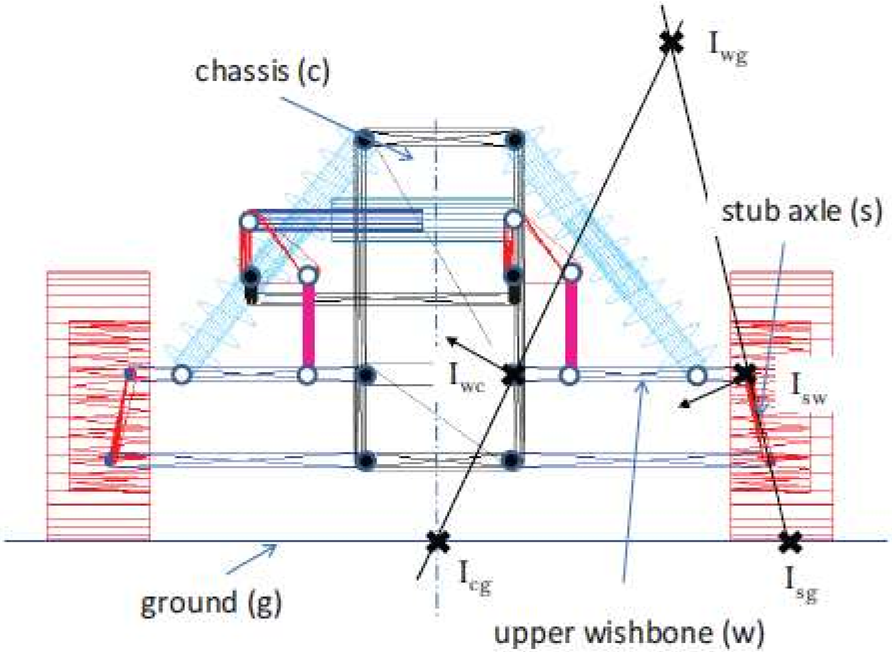


Roll center



Hydraulic cylinder
Rocking-levers
Connecting rod
d_w
Platform fixed-point
a_c
l_w
Wheel roll center
Chassis roll center

Kinematic characteristics of the mechanism

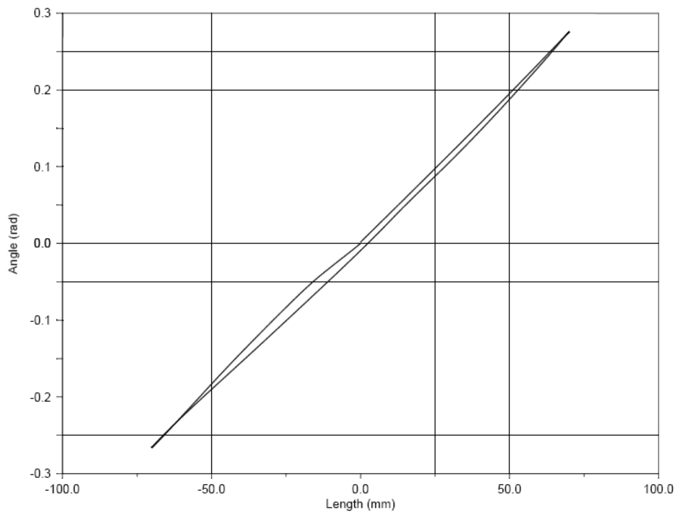


$$\frac{\delta\lambda}{\delta\phi} \approx 2d_w\left(\frac{a_c}{l_w}+1\right) = k_m$$

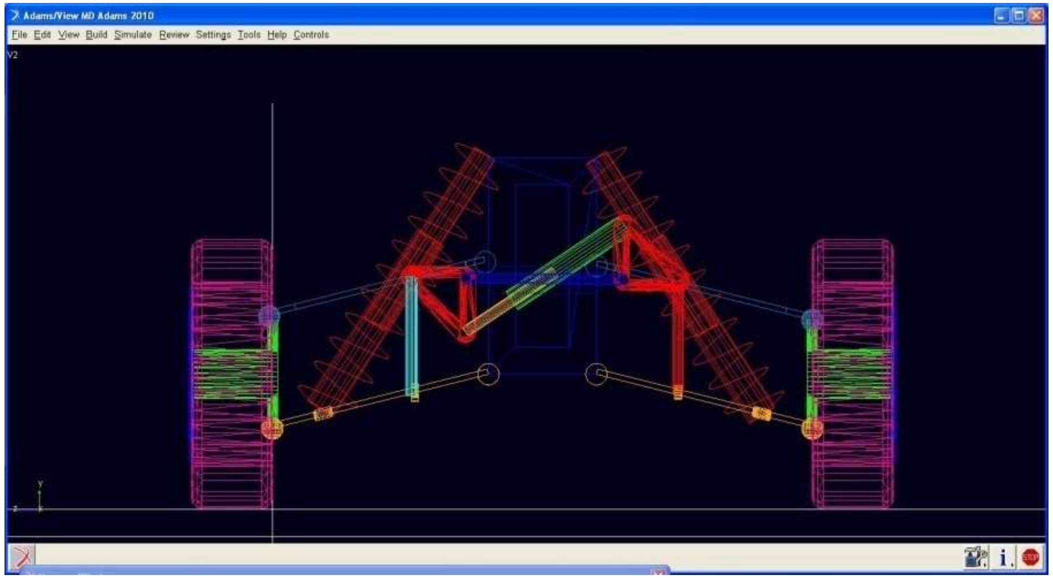
$$\nu = k_m\dot{\phi}$$

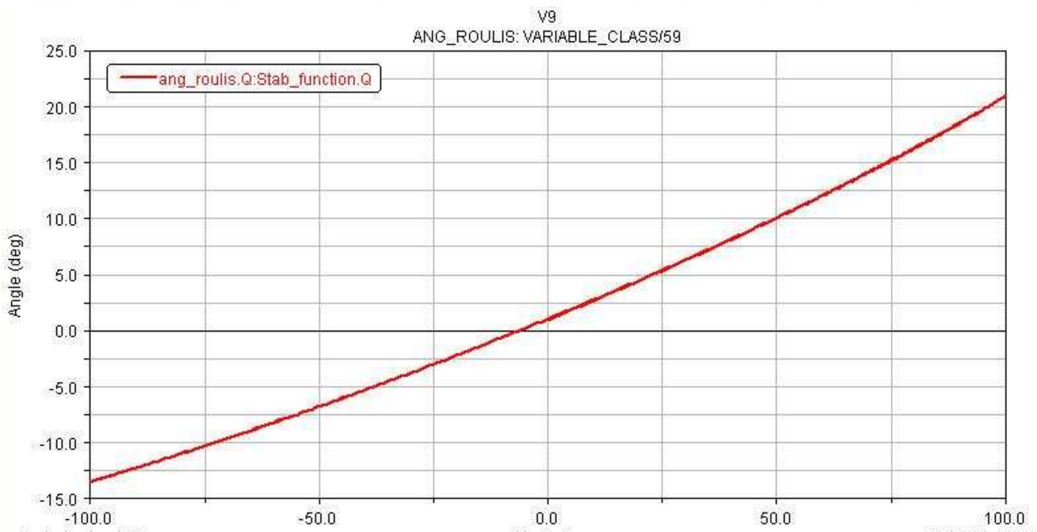
- Same kinematics for front and rear axle
- Hydraulic energy
  - By-pass mode (double-rod cylinder)
  - Inhibition of the Anti-roll system (hydraulic distributor)

Roll angle vs Cylinder stroke

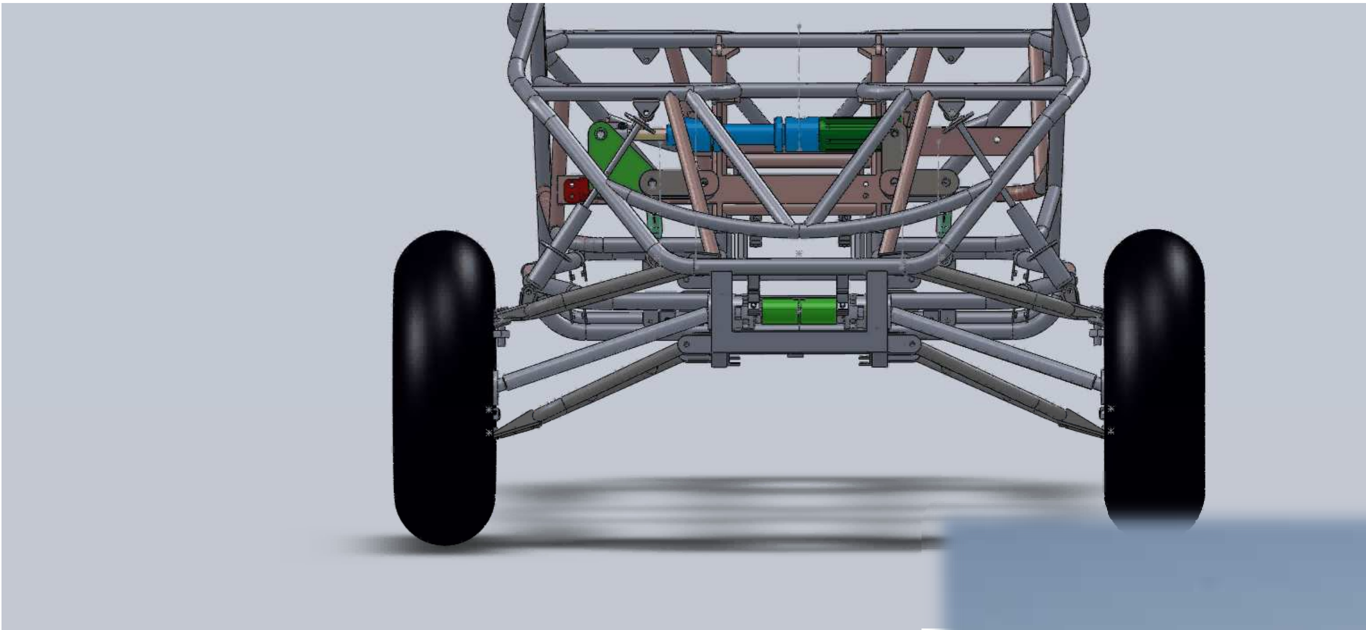


Alternatives



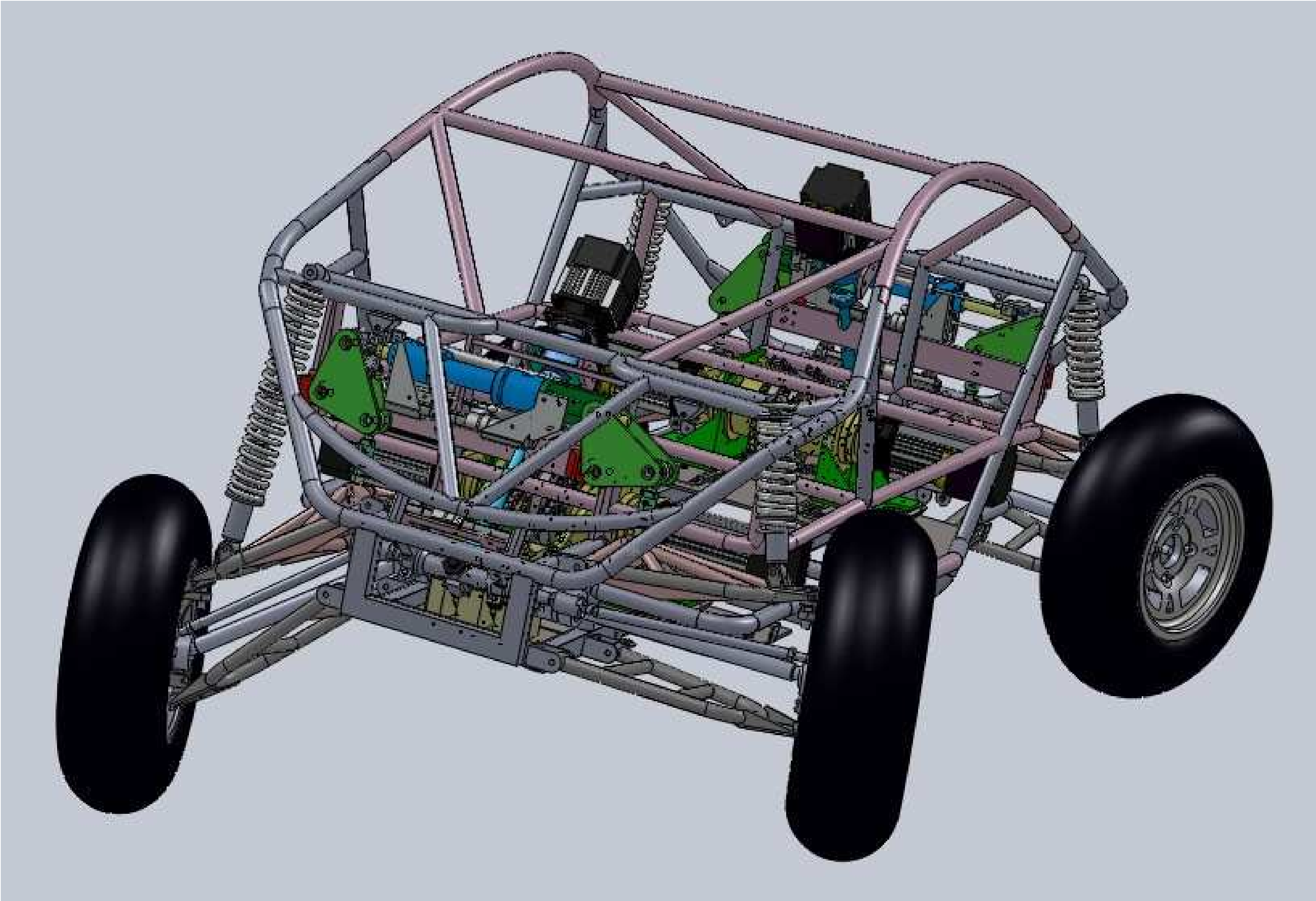


Integration on a commerical chassis

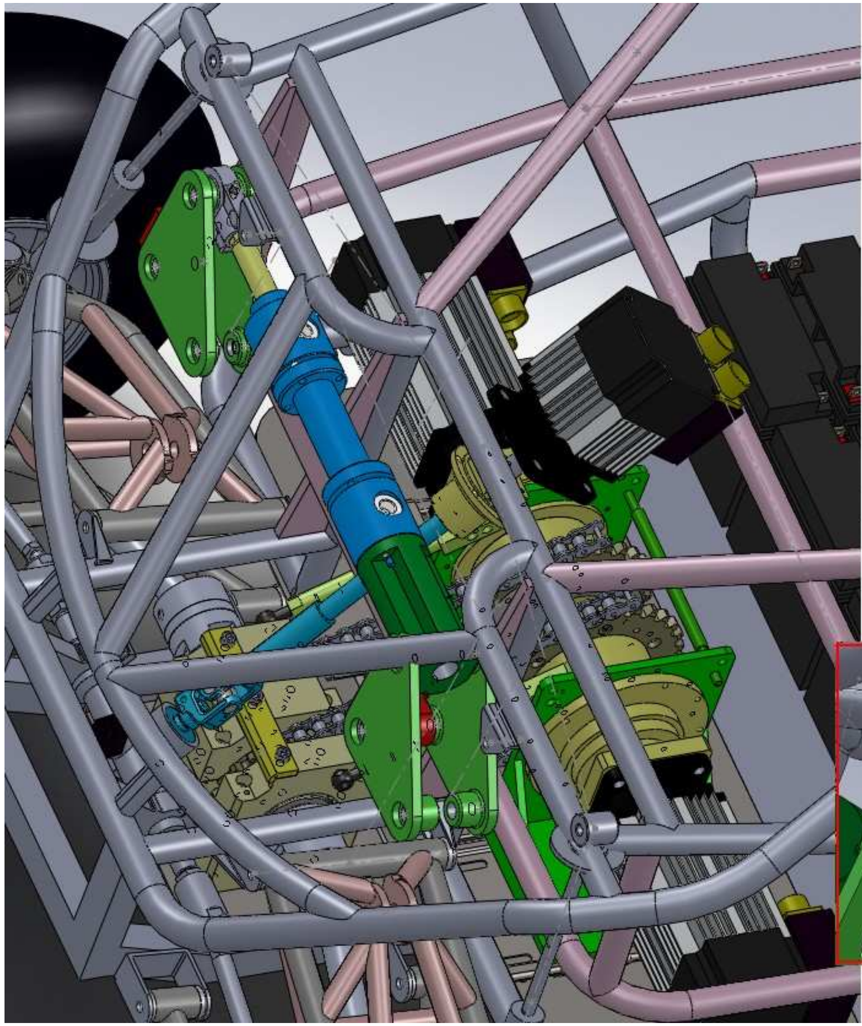


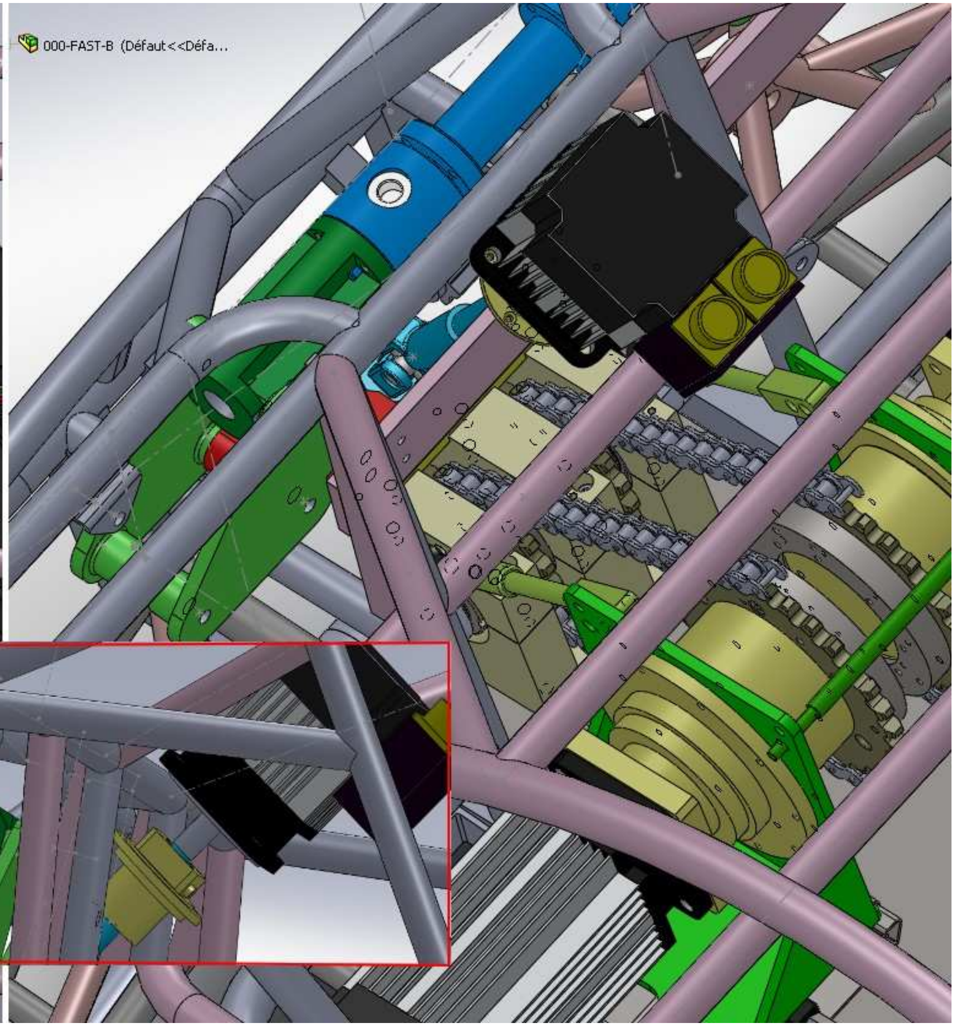
BOOXT buggy gokart 1100, 650 buggies 250 quad homologué 50 quads 500; scooter 50.flv

CAD Model



CAD Model

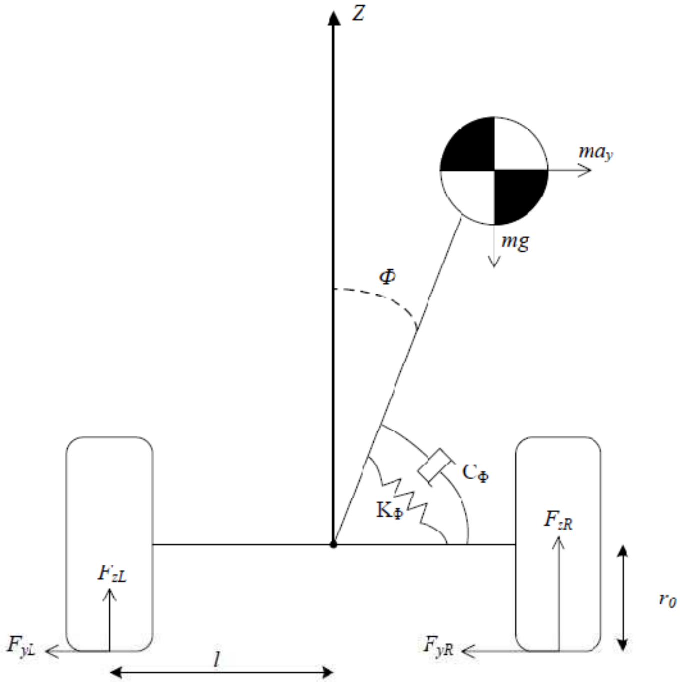




Roll model (Sprunged mass dynamics)

$$\dot{V}_\phi I_{xs} = M_s h_p(\dot{V}_y + V_\psi V_x) + I_{xz}\,\dot{V}_\psi + M_s g h_p \phi - 2(k_\phi \phi + c_\phi V_\phi) + k_m F_a$$

$$\dot{x}_\phi = \begin{pmatrix} 0 & 1 \\ a_{21} & a_{22} \end{pmatrix} x_\phi + \frac{1}{I_{xs}} \begin{pmatrix} 0 \\ M_s h_p(\dot{V}_y + V_\psi V_x) + I_{xz}\,\dot{V}_\psi \end{pmatrix} + \begin{pmatrix} 0 \\ 1/I_{xs} \end{pmatrix} k_m F_a$$



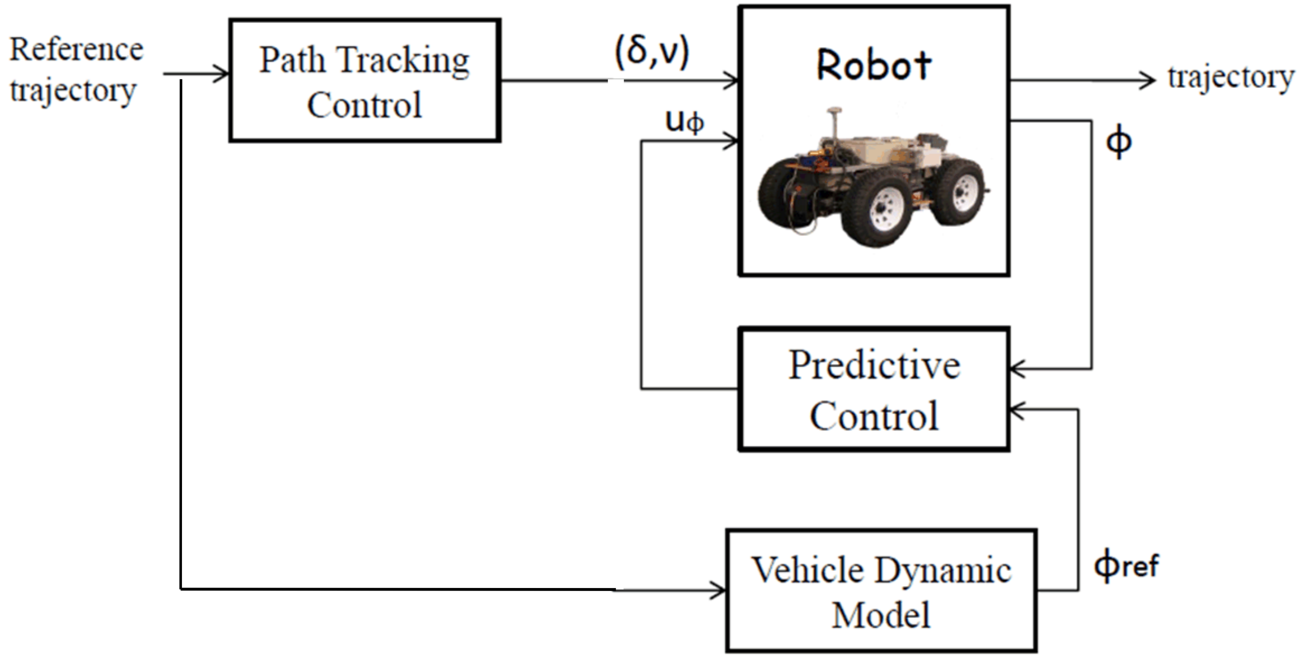
$$\dot{x}_\phi = \begin{pmatrix} \phi \\ \dot{\phi} \end{pmatrix}$$

$$a_{22} = -2c_\phi$$

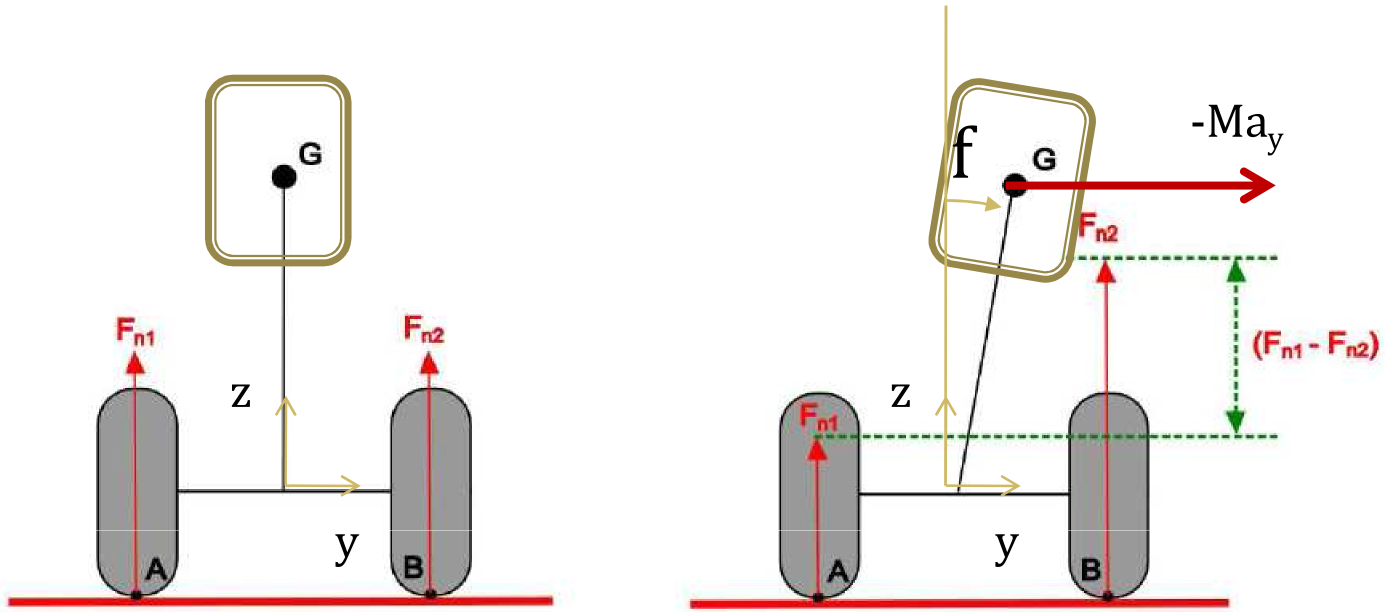
$$a_{21} = (M_s g h_p - 2k_\phi)/I_{xs}$$

Control design

- What is the control goal ? Stability ?
- Define a reference ? Roll angle reference ?
- Must depend on robot trajectory
- Supposed known the robot trajectory



Stability index : Lateral Load Transfert



$$LLT = \Delta F_z = \frac{M_s g b}{(a+b)l} h_p \phi + \frac{Mh}{l} a_y$$

$$\phi_{ref} = -\frac{MH(a+b)}{mgbh} a_y(t)$$

MPC (Model Predictive Control)

$$u_\phi = u_{\phi l} + u_{\phi c}$$

Predictive control $u_{\phi c}$

Linearzing control term

$$u_{\phi l} = M_s h_p (\dot{V}_y + V_\psi V_x)$$

Minimizing the quadratic criteria along a receding time horizon p:

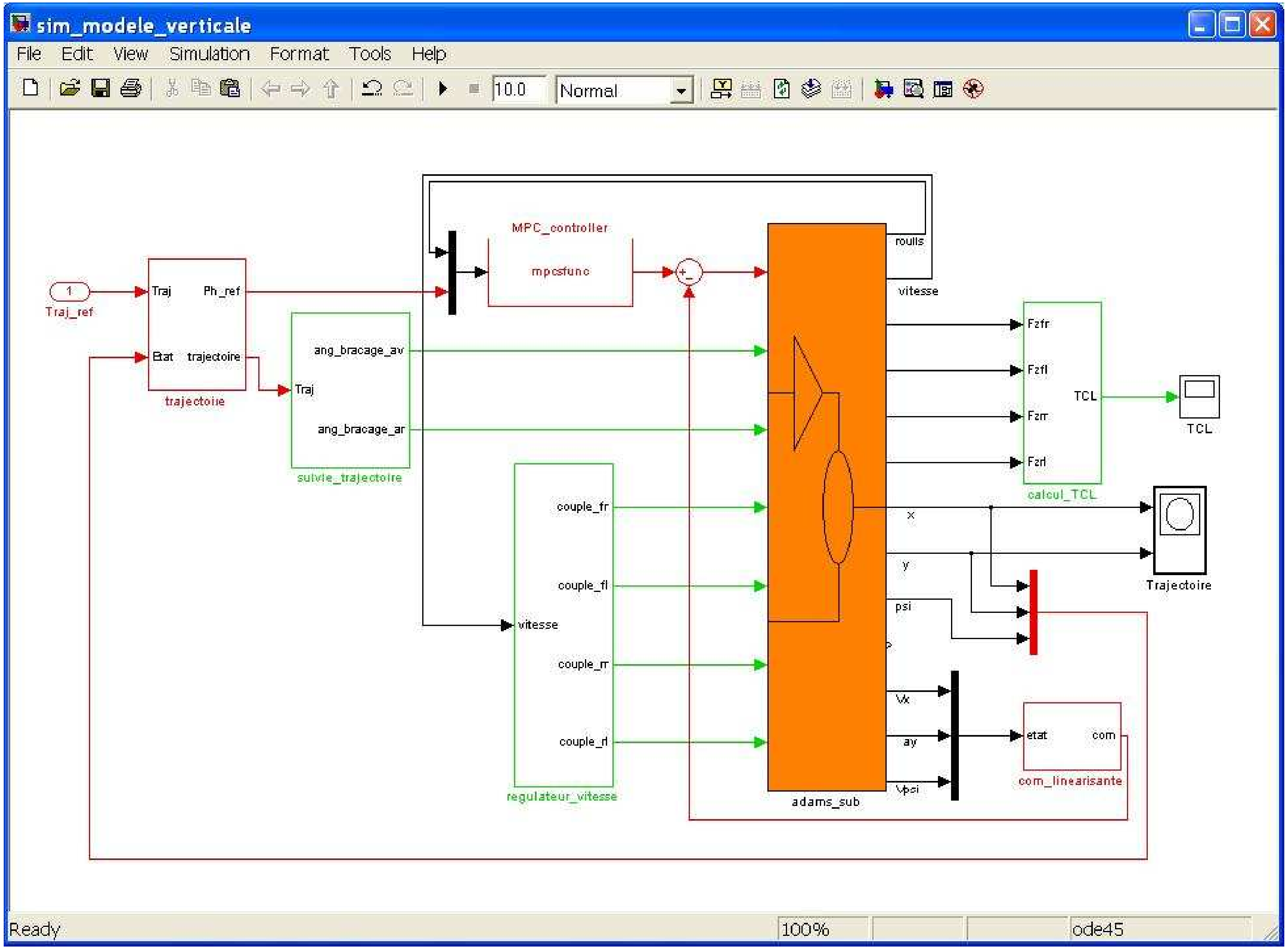
$$J\left(x_\phi(t), \Delta U_t\right) = \sum_{i=t+1}^{t+p} \left\| \phi_{i,t} - \phi_{ref\,i,t} \right\|_Q^2 + \sum_{i=t}^{t+c-1} \left\| \Delta u_{i,t} \right\|_R^2$$

$$\dot{x}_\phi = A_\phi\, x_\phi + B_\phi\, u_{\phi c}$$

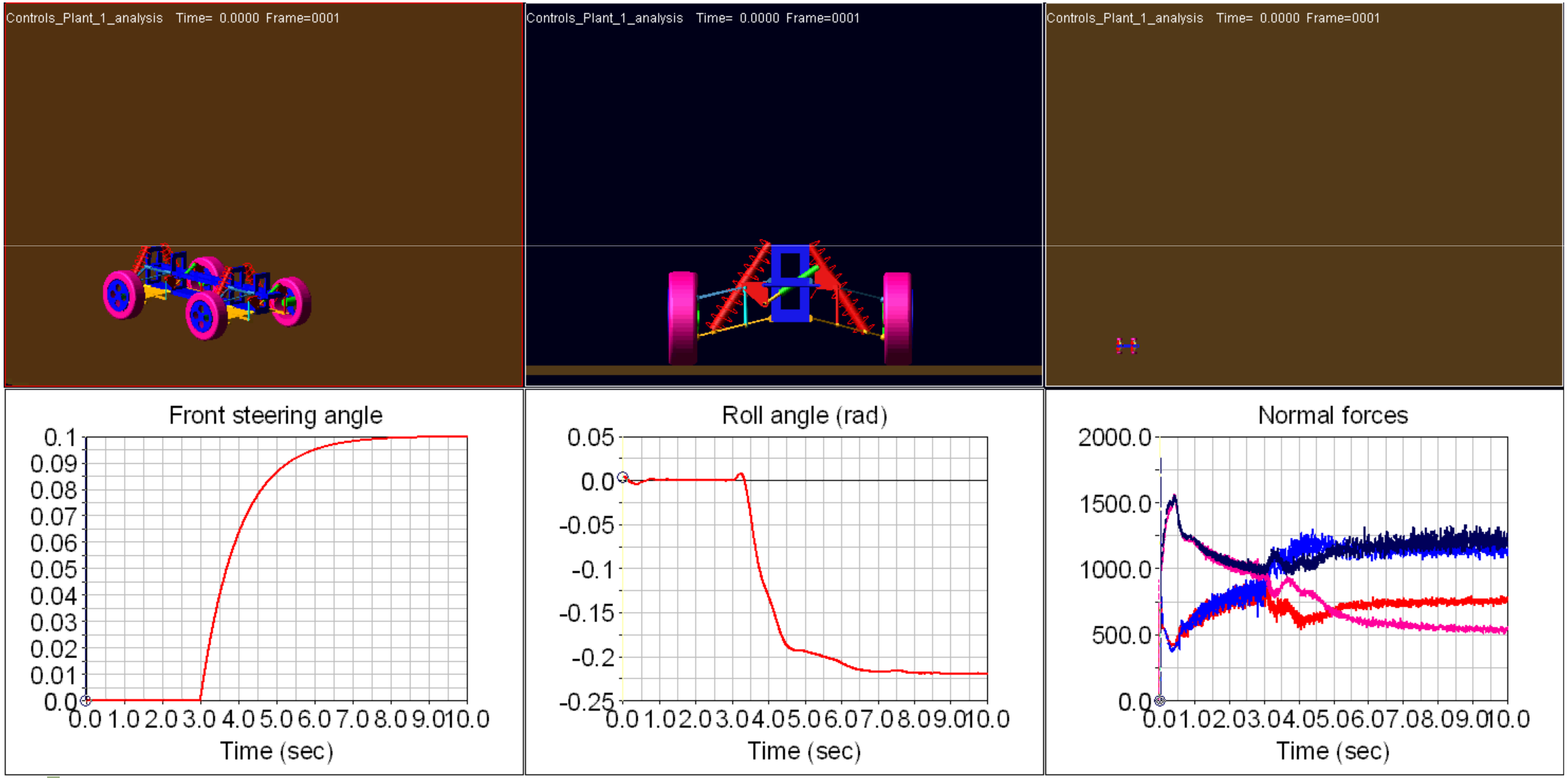
$$\Delta U_t = [\Delta u(t), \dots, \Delta u(t + c - 1)]$$

$$u_{\phi c}(t) = u_{\phi c}(t - 1) + \Delta u(t)$$

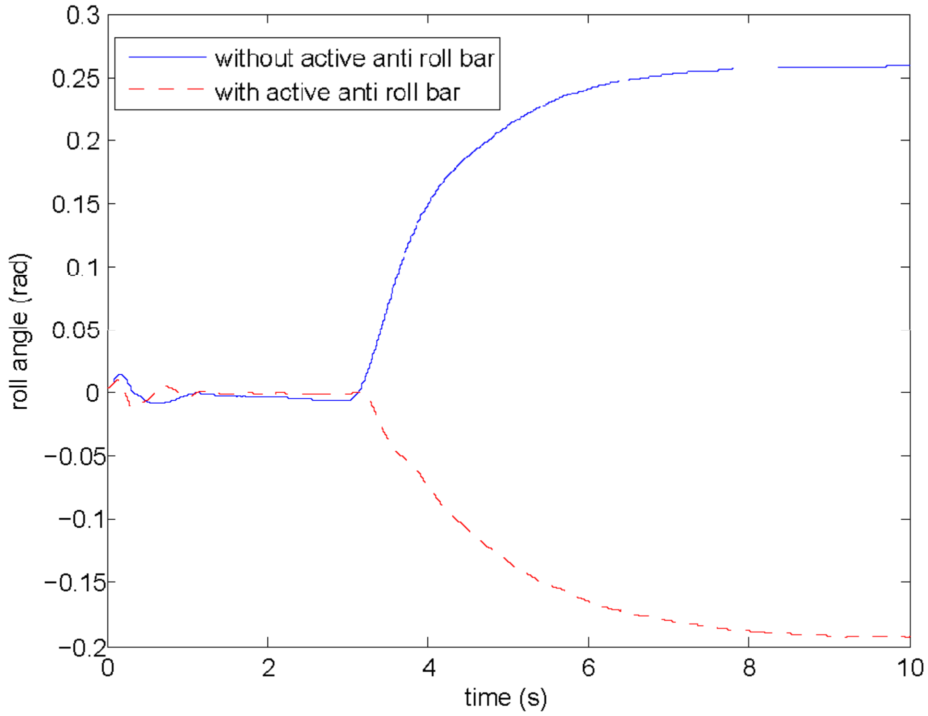
Co-simulation Adams/MatlabSimulink



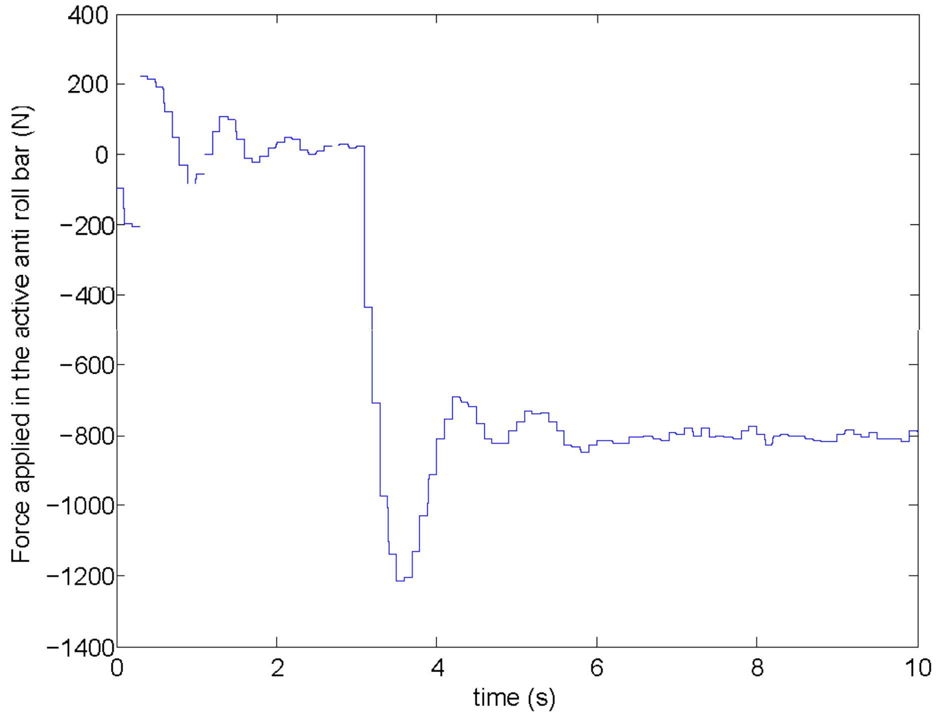
Co-simulation Adams/MatlabSimulink



•Results

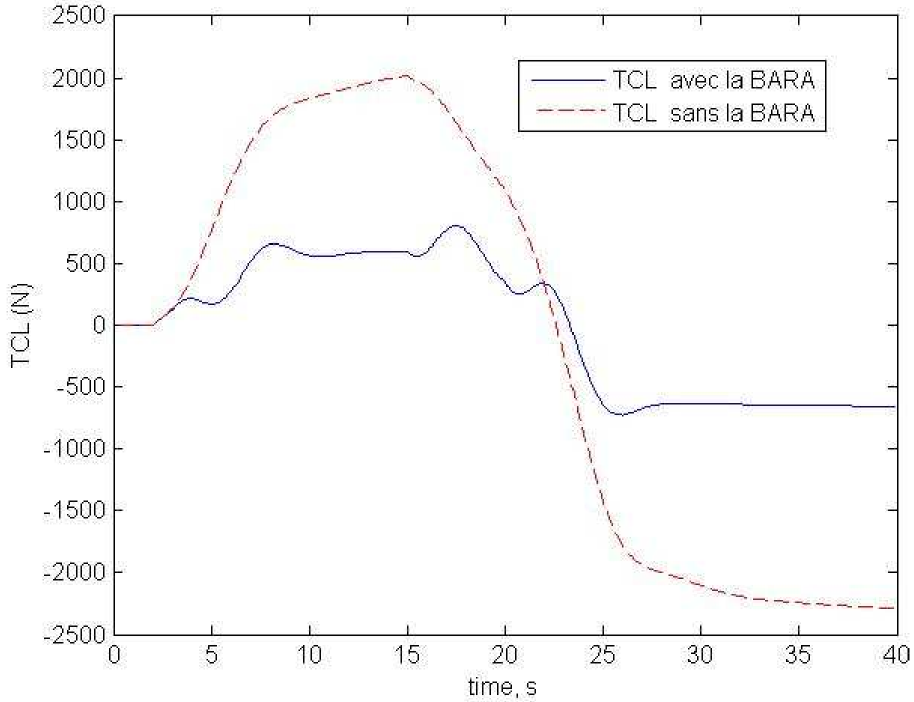


Roll angles with and without control

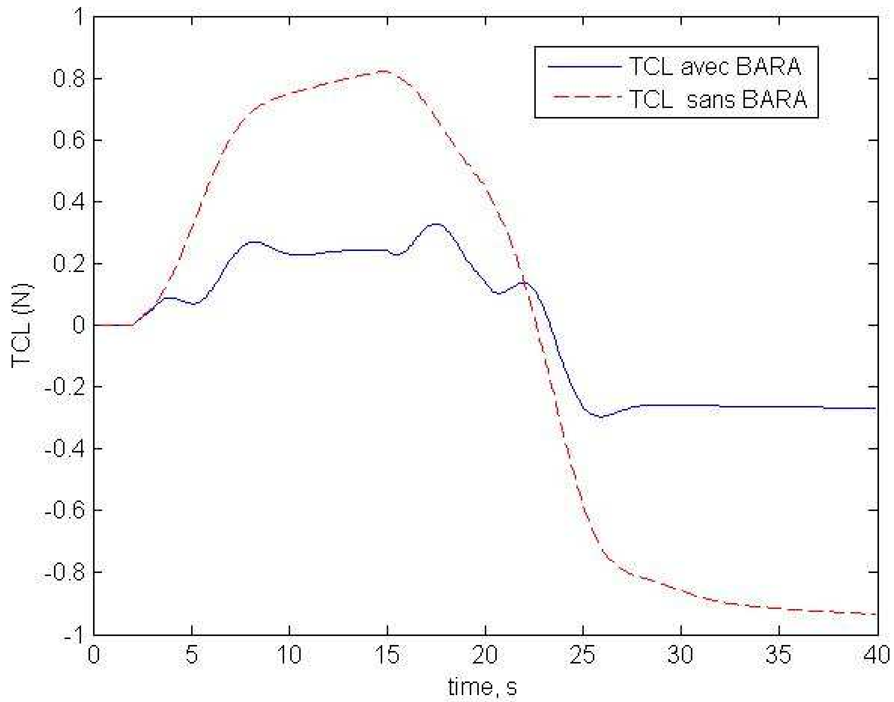


Control input : Cylinder force

•Lateral Load Transfer LLT

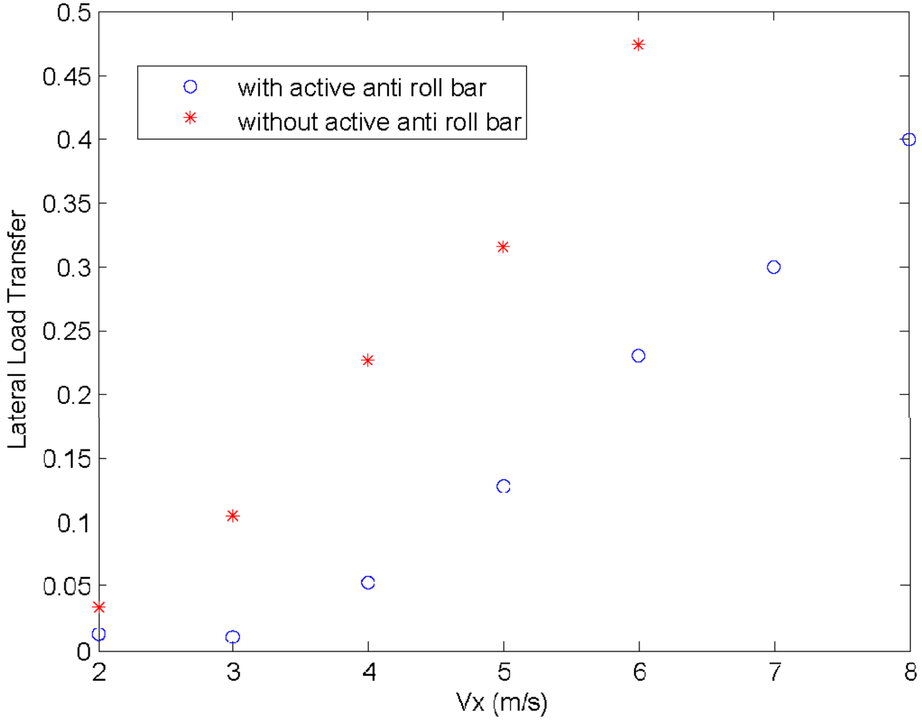


Lateral load transfer

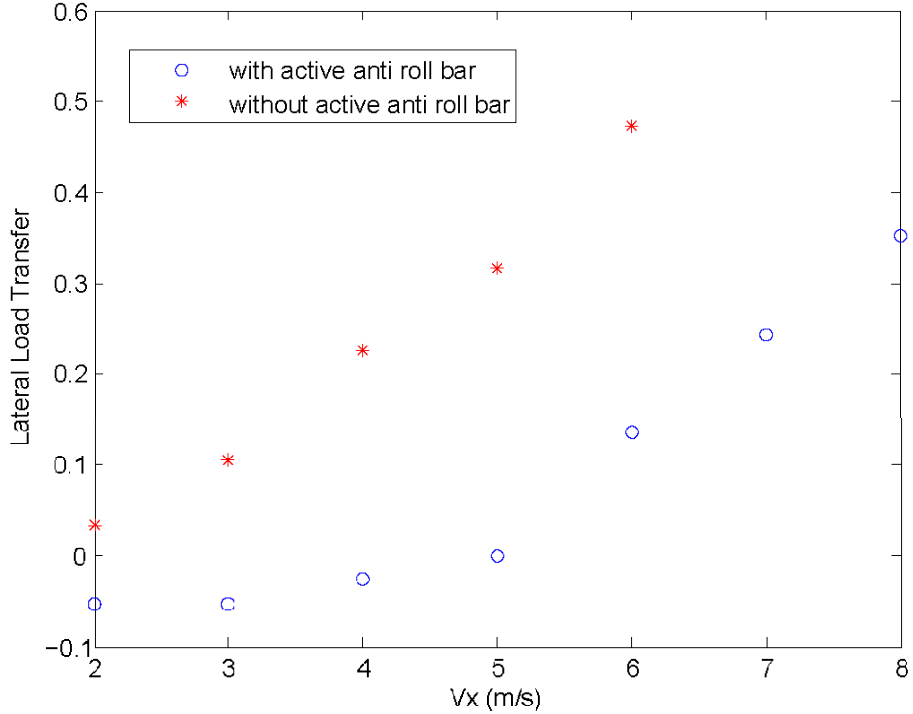


Normalized Lateral Load Transfer

Stability as function of velocity



Front axle



Rear axle

Increase stability margin
Increase the robot task performance
Can be integrated to conventional chassis with suspension