Heavy vehicle dynamics optimization

Yerlan Akhmetov[1,3], Didier Rémond[1], Lionel Maiffredy[1], Wilfrid Marquis-Favre[2], Michael Di Loreto[2], Virginie Harth[3]

[1]LaMCoS, INSA-Lyon [2]Ampère, INSA-Lyon [3]Volvo 3P

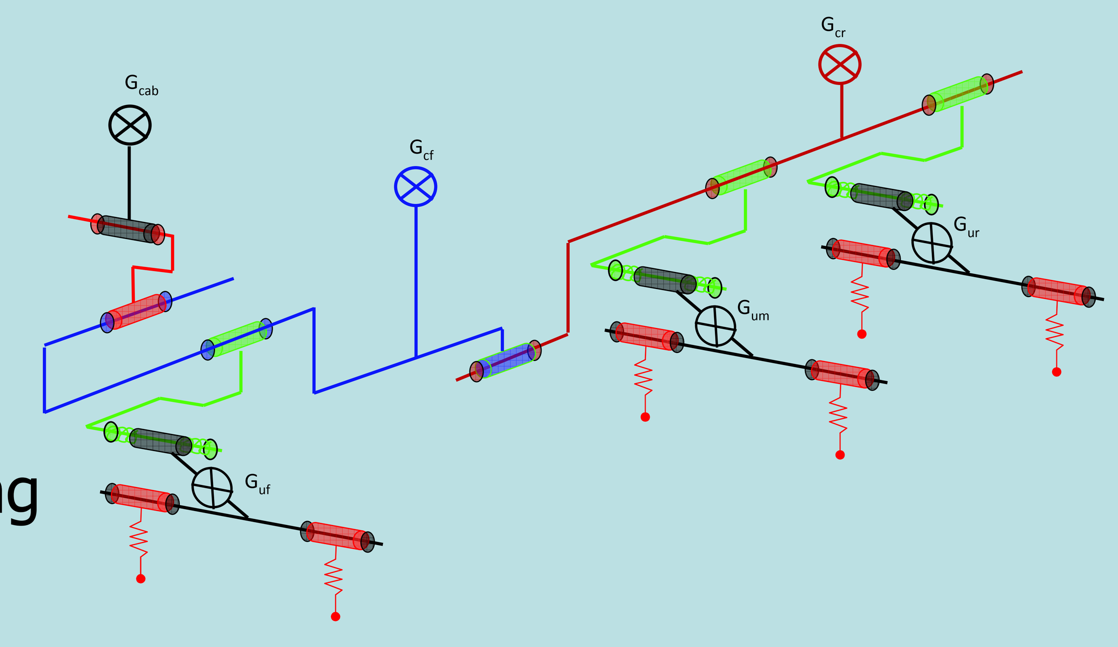
Background

Heavy vehicles are mainly exposed to two principal risks on the road: rollover and lateral instability. Conventional ESP permits to solve partially the problem by using the differential braking, but despite all benefits of the system the vehicle performances can still be improved. This improvement can be achieved by combining the braking action to the actions of other available actuators installed on the vehicle such as steering system and active/semi-active suspensions. There are many different ways to integrate the actuators into global chassis control such as supervisory, decentralized, centralized control techniques. In our study we adopt a promising centralized control, by consequence a high vehicle's over-actuation problem has to be solved. The over-actuation of the heavy vehicle is handled by using the control allocation technique which is already applied in the domains of aeronautics, marine vessels, robotics and studied for road vehicles. The study includes the vehicle dynamics and actuators modeling and controller design.

Vehicle dynamics modeling

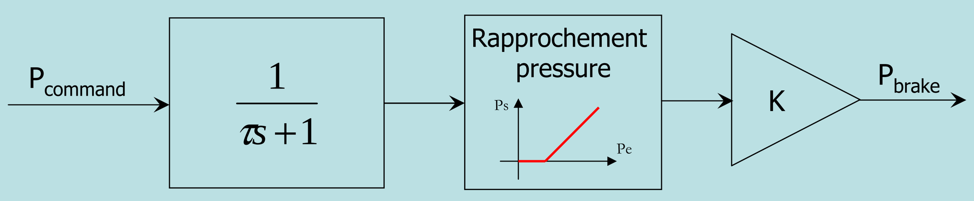
Solo vehicle P6x2Tag:

- Flexible frame
- Suspended cab
- Trailing arms suspensions modeling
- Pacejka tire model

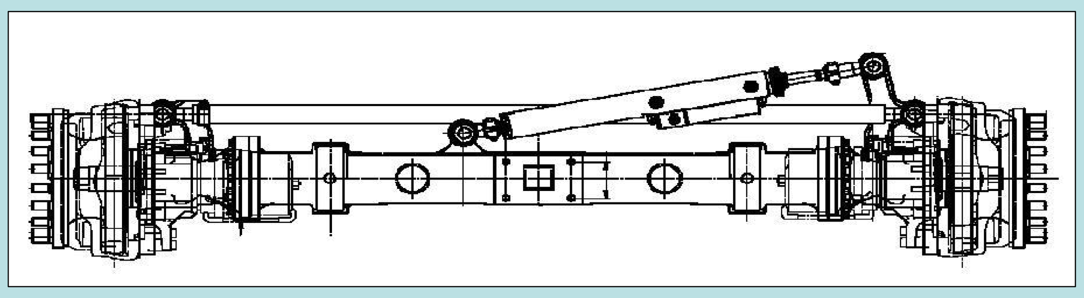


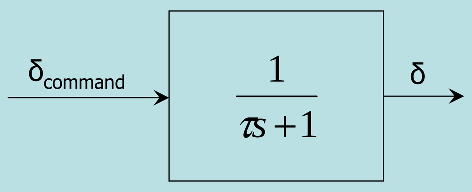
Actuators modeling

- Braking system

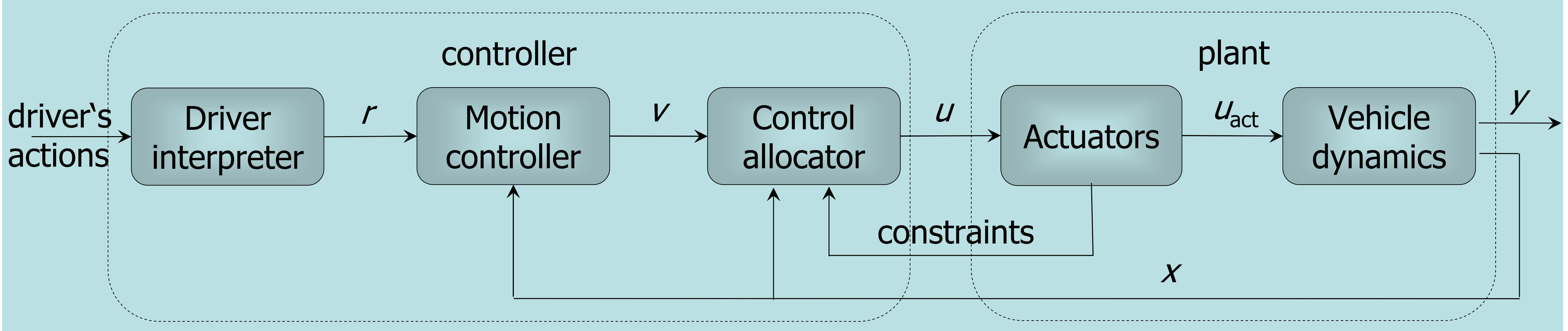


- Rear Active Steering





Modular control design



Vehicle dynamics:

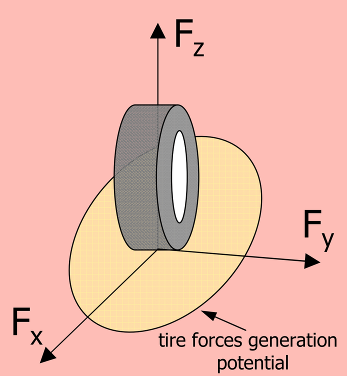
$$\dot{x} = f(x) + g(x)u \qquad \text{or} \qquad \dot{x} = f(x) + v$$
$$y = h(x) \qquad\qquad\qquad y = h(x)$$

- **Driver interpreter** (linear one-track model): translates drivers actions into desired vehicle's trajectory $r \in \mathbf{R}^n$
- **Motion controller**: defines total control effort $v \in \mathbf{R}^n$ to be applied to the vehicle
- **Control allocator**: maps total control effort vector v into actuators inputs $u \in \mathbf{R}^m$

For over-actuated systems $m > n$

Control requirements

- Vehicle rollover prevention
- Vehicle yaw control
- Optimal use of the tire potential
- Handle actuators redundancy and constraints



Control allocation

Solves constrained underdetermined (m > n) problem:

$$g(x)u = v$$

- Linear case is considered: $Bu = v$
- u is constrained in position and in rate

$$\underline{u} \leq u \leq \overline{u}$$

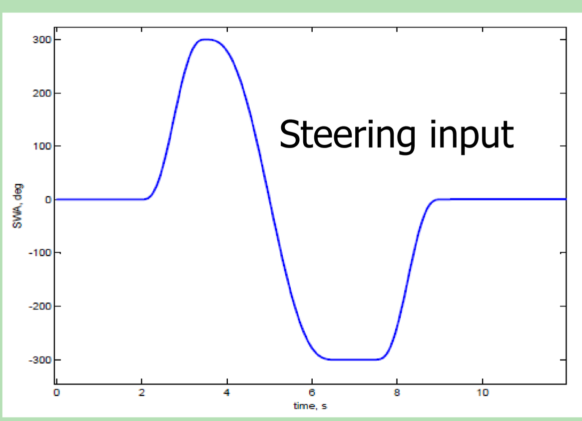
- Possible solution: real-time constrained convex optimization

$$u = \arg\min\left(\left\|W_u(u - u_{des})\right\|_p + \gamma\left\|W_v(Bu - v)\right\|_p\right)$$

Exemple: Yaw control

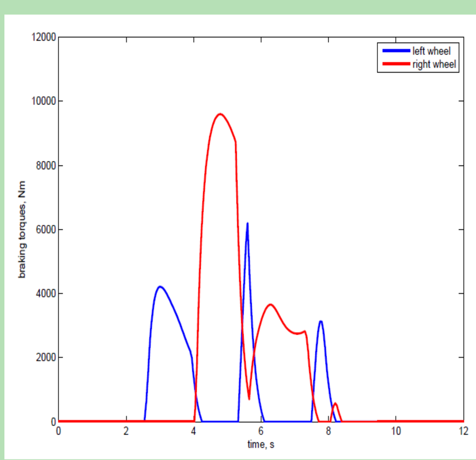
Maneuver definition

Initial speed: 40 km/h
Steering input: Sine with dwell
Brake/gas pedals: No action
Adherence: 50%

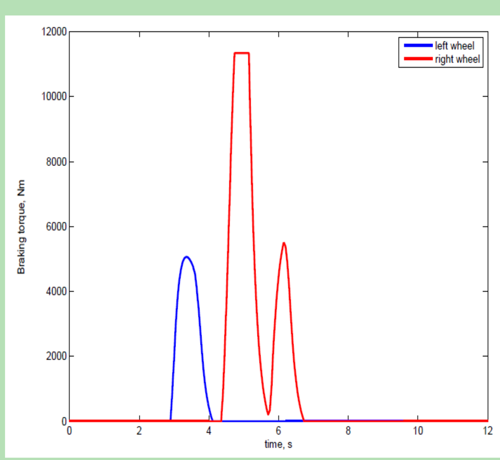


Controlled vehicle: actuator inputs

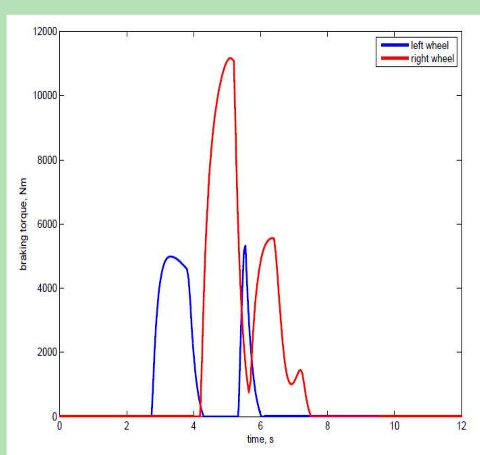
Braking torques



Rear axle

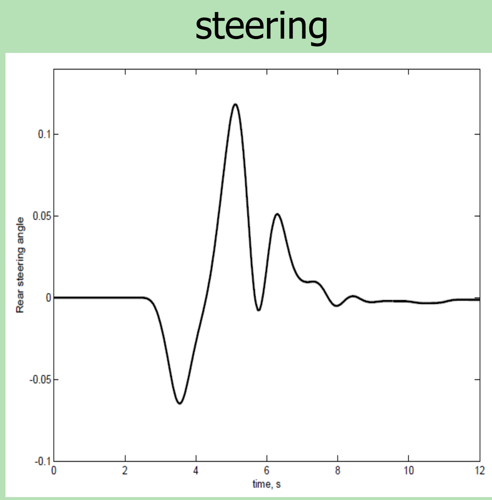


Middle axle

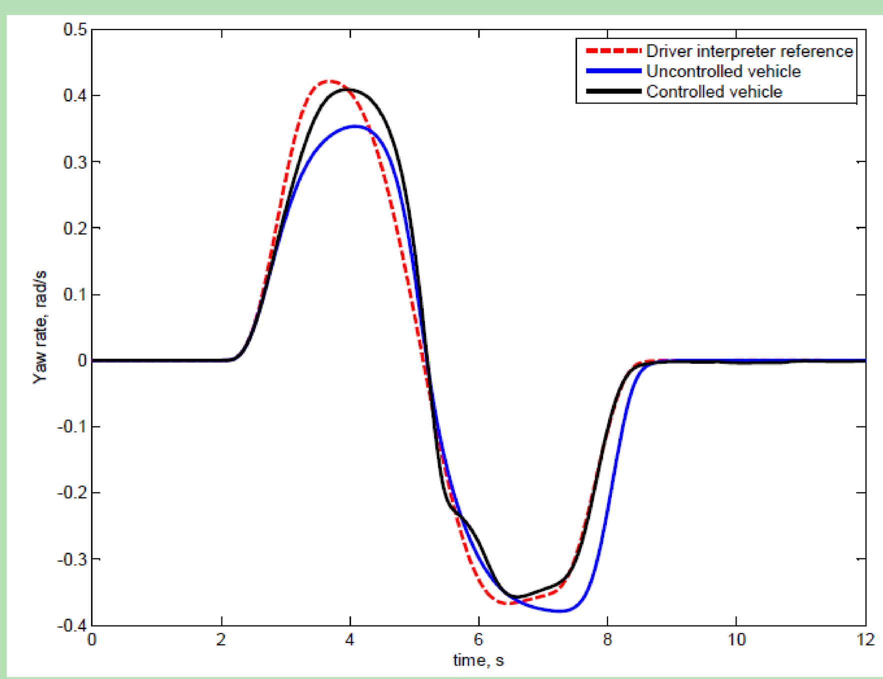


Front axle

Rear active steering



Vehicle's yaw rate



yerlan.akhmetov@insa-lyon.fr

LaMCoS, Université de Lyon, CNRS, INSA-Lyon UMR5259, 18-20 rue des Sciences - F69621 Villeurbanne Cedex