



## **New trends in vehicle dynamics: from modelling to control**

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# New trends in vehicle dynamics: from modelling to control.

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## I. SESSION TOPIC

Over the past few years, automotive engineering has been characterized by rapid growth in active systems. Many research works have therefore been devoted to the control of such active subsystems, as braking, steering or suspension actuators. In particular the use of different actuators (braking, steering, suspension ...) allow to tackle emergency situations such as rollover, too large lateral and yaw accelerations, slipping .... [1], [2], [3].

On the other hand the control of suspension systems still remains of interest as this subsystem influences comfort and road handling as well [4], [5]. New advances control approaches such as  $H_\infty$  approach for Linear Parameter Varying systems and Model predictive control have shown to be efficient in this framework [6], [7], [8].

On the other hand, the complex and multivariable inherent nature of the vehicle asks for the need of integrated approaches, in order to account for the coupling dynamics (roll, yaw, pitch, vertical, longitudinal and lateral behaviors) and to deal with different actuators.

The aim of this invited session is to give some recent results on vehicle dynamics control through the use of new innovative systems and control tools.

## II. SESSION GOALS AND COHESIVENESS

The session goal and cohesiveness is to present various recent and innovative works where the vehicle dynamical behavior is improved thanks to the use of different kind of actuators (suspension, braking, steering,...). This needs new methods for modelling and control of subsystems and of the vehicle.

The session will be organized as follows:

- Papers 1 and 2 concern the development of control design methods for semi-active suspensions.
- In paper 3, a LPV approach is considered to control the vehicle dynamics (e.g. rollover) through active suspensions, even in the presence of fault actuators.
- Paper 4 concerns the application of nonlinear Internal Model Control for the yaw dynamics.
- In paper 5, a new LPV approach is proposed for the vehicle dynamics control using braking and steering actuators.
- In paper 6, the braking subsystem is considered for the stop-and-go system.
- In Paper 7 a new method for vehicle speed estimation is proposed
- Paper 8 deals with the  $H_\infty$  control of a landing gear steering system.

## III. PAPERS OF THE SESSION

### A. Paper 1

**Title:**A new concept of semi-active suspension with controllable damper and spring.

**Authors:**Cristiano Spelta, Maurizio Cutini, Carlo Bisaglia, Simone A. Bertinotti, Sergio M. Savaresi, Fabio Previdi and Paolo Bolzern

The problem considered in this paper is the design and analysis of implementable architectures and control strategies for semi-active suspensions characterized by a regulation of both damping and stiffness coefficients. Nowadays reliable and cost-effective technologies for the modulation of spring coefficient are not available. The first contribution of this paper is the introduction of a suspension architecture that makes possible the emulation of the behavior of an ideal suspension with variable spring. Taking into account the comfort objective, a full analysis on the advantages and drawbacks of this kind of suspension is provided. The main trade-off arising from the use of this kind of suspension consists on one hand in a better filtering of the road disturbances due to possibility of modulating the spring characteristic, and on the other hand in the end-stop hits that occur due to the spring stiffness modulation. This paper proposes a novel comfort-oriented stiffness-damping control algorithm that overcomes this critical trade-off while ensuring better performances compared to classical semi-active strategies with damping modulation only.

## **B. Paper 2**

**Title:**Semi-active  $H_\infty$ /LPV control for an industrial hydraulic damper

**Authors:** S. Aubouet, L. Dugard, O. Sename, B. Talon, C. Poussot-Vassal

In this paper, a semi-active control strategy is developed to improve comfort and roadholding of a ground vehicle. The system under study is an industrial damper designed by SOBEN to be controlled by means of a small servomechanism. The main controller is a static state feedback controller synthesized in the  $H_\infty$ /LPV framework to compute the required damping force that minimizes the movements of the vehicles body on one hand, and the deflection of the tire on the other hand. A scheduling strategy is developed on the basis of the real damper behavior to improve performances without using active damping forces which would be useless for such a semi-active system. Here the controller takes the constraints of the technology and the damper behavior into account and is easy to implement in an industrial application. The control of the servomechanism is provided by a simple PID controller that makes the damper provide the required force. The performance of the overall is illustrated on an identified nonlinear model of the damper included into a quarter car model. The comfort and roadholding level of the semi-active suspension are studied using some adapted criteria and compared with the passive ones. Some simulations emphasize the comfort and roadholding improvements of this control strategy that will be tested by SOBEN on the new Renault Laguna III in the next weeks.

## **C. Paper 3**

**Title:**LPV-based reconfigurable chassis design

**Authors:** P. Gaspar, Z. Szabo, J. Bokor

This paper proposes the design of reconfigurable and fault-tolerant suspension systems in road vehicles. The purpose of the suspension system is to improve passenger comfort, road holding and safety during travel and various maneuvers. When a rollover is imminent the suspension system generates a stabilizing moment to balance the overturning moment and reduce the rollover risk. When pitching dynamics is significant during abrupt and hard braking the suspension system generates a moment to improve road holding and comfort. In the modeling the nonlinearities of the suspension system, the changes in the forward velocity and the change of the adhesion coefficient between the tire and the road are taken into consideration. The effects of the longitudinal or lateral load transfers during maneuvers or abrupt hard brakings are monitored in order to reduce their harmful effects on handling and comfort. Moreover, when a fault (loss in effectiveness) occurs at one of the suspension actuators a reconfiguration is required in order to guarantee fault-tolerant operation. In the control design the bound of the unmodelled dynamics is also taken into consideration. The design of the proposed control system is based on an Hinf Linear Parameter Varying (LPV) method that uses monitored scheduling variables of the travel.

## **D. Paper 4**

**Title:** A nonlinear IMC approach to vehicle yaw control

**Authors:** M. Canale, C. Novara, M.C. Signorile

The use of a novel approach to nonlinear internal model control (NIMC) is investigated in vehicle yaw control context. The proposed control technique is based on recent results for left inversion of nonlinear dynamical systems from data in a set membership (SM) environment which avoid the direct derivation of the inverse model. Such inverse model is the basic element of the NIMC controller which contains also a nonlinear model of the vehicle dynamics identified via SM methodologies directly from data. Performance of the introduced control scheme is tested through simulation results obtained using a nonlinear model of the vehicle.

## **E. Paper 5**

**Title:**Robust Automotive Steering and Braking Controller

**Authors:** Charles Poussot-Vassal, Olivier Sename and Luc Dugard

This paper is concerned with the synthesis of a robust steering and braking controller to enhance automotive vehicle yaw stability and lateral performances. The contribution of this work is to provide a methodology, based on the  $\mathcal{H}_\infty$  theory, to synthesize such a controller, while taking into account the braking actuator limitations. In the proposed solution, the controller structure is designed in an original way and is coupled with a local ABS strategy to guarantee slip stability and make the solution complete for implementation issues. Time and frequency - domain simulations on a complex nonlinear full vehicle model, subject to critical driving situations, shows the reliability and efficiency of the proposed solution.

## **F. Paper 6**

**Title:** Model free control of automotive engine and brake for Stop-and-Go scenario

**Authors:** Sungwoo Choi, Brigitte d'Andréa-Novél, Michel Fliess, Hugues Mounier, Jorge Villagra

In this paper, we propose a model free control approach to deal with automotive longitudinal control in the case of Stop-and-Go scenario. Stop-and-Go attempts to place automatically the vehicle at safe distances in urban environments. In

this case, accelerating and braking maneuvers are very demanding in short time intervals, but the corresponding torques are often difficult to obtain because of the uncertainty of dynamics, not only at the chassis level but also at the engine/brake model. In order to compensate the losses related to the neglected dynamics, a free model control approach will be used at the engine/brake level. Simulation results are presented to illustrate our method.

### G. Paper 7

#### **Title: Vehicle Speed Estimation with Compensation of Wheel Measures Noise**

**Authors: Osvaldo Barbarisi, Luigi Glielmo**

The longitudinal vehicle speed estimation is commonly realized by using longitudinal acceleration sensor and rotational speed sensors of each wheel. This information is depreciated when during regular manoeuvres such as steering, braking, accelerating, the slip ratio of a wheel is too high. In this paper we introduce a Kalman filter which considers the stochastic properties of the signal.

### H. Paper 8

#### **Title: Reduced order $H_\infty$ control design of a Nose Landing Gear steering system**

**Authors: Gaëtan Pouly, Jean-Philippe Lauffenburger and Michel Basset**

In recent years, aeronautics has witnessed the emergence of increased electrical on board equipment. Today, the reverse thrust, the engine starter, the braking system can operate electrically. The present paper describes the use of a new nose landing gear steering system, using an electromechanical actuator. More specifically, a reduced order  $H_\infty$  solution helps to control the actuator and so, to steer the aircraft front wheel. The paper first presents the nose landing gear model coupled with the electromechanical actuator, then discusses the use of the HIFOO tool to synthesize a reduced order controller. Various control strategies are considered, different simulations are proposed and finally, the impact of the controller order is discussed.

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