Editorial

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Biographical notes: Hocine Imine received his Masters and PhD in Robotics and Automation from Versailles University, France, in 2000 and 2003, respectively. From 2003 to 2004, he was a researcher at the Robotic Laboratory of Versailles and Assistant Professor at Versailles University. In 2005, he joined IFSTTAR, where he is currently a researcher. He is involved in different projects such as Véhicule Interactif du Futur (VIF) and Heavyroute (Intelligent Route Guidance for Heavy Traffic). He is also responsible of the research project PLInfra on heavy vehicle safety, assessment of their impacts on pavement and bridges. He is a member of IFAC Technical Committee on Transportation Systems (TC 7.4). His research interests include intelligent transportation systems, heavy vehicle modelling and stability, diagnosis, non-linear observation and non-linear control. He has published two books, over 60 technical papers and several industrial technical reports.

Leonid M. Fridman received his Masters in Mathematics from Kuibyshev (Samara) State University, Samara, Russia, in 1976, PhD in applied mathematics from the Institute of Control Science, Moscow, Russia, in 1988 and the DSc in control science from the Moscow State University of Mathematics and Electronics, Moscow in 1998. From 1976 to 1999, he was with the Department of Mathematics, Samara State Architecture and Civil Engineering University. From 2000 to 2002, he was with the Department of Postgraduate Study and Investigations, Chihuahua Institute of Technology, Mexico. In 2002, he joined the Department of Control Engineering and Robotics, National Autonomous University of Mexico, Mexico. He was an Invited Professor in 15 universities and research centres in France, Germany, Italy, Israel and Spain. He is the author and editor of five books and ten special issues on sliding mode control and an author of more than 300 technical papers. His main research interest is variable structure systems. He is an Associate Editor of the *International Journal of System Science* and the *Journal of the Franklin Institute, Nonlinear Analysis: Hybrid Systems*. He is on the Conference Editorial Board of the IEEE Control Systems Society, a member of the Technical Committee (TC) in the Variable Structure Systems and Sliding Mode Control of IEEE Control Systems Society and the TC in the Discrete Events and Hybrid Systems of IFAC. He is a winner of the Scopus prize for the best cited Mexican Scientists in Mathematics and Engineering 2010 award.

Welcome to the Special Issue on Advances in Variable Structure Systems in Automotive Applications.

During the past two decades, significant progress has been made in the field of higher order sliding mode controllers and observers. These observers/controllers ensure the insensibility of the system with respect to matched smooth uncertainties/perturbations by usage of the absolutely continuous controllers. Moreover, higher order sliding mode-based observers ensure the best possible asymptotic accuracy of the state observation and unknown inputs identification with respect to sampling step and deterministic bounded noises. This explains why several researchers have started to use the new techniques for the vehicle dynamics analysis and design.

The objective of this Special Issue of *IJVD* is to present recent research concerning vehicle dynamics, going from the dynamics observation (acceleration, side slip, force estimation, etc.), parametric identification, risk prediction (rollover, jackknifing, etc.) and vehicle control (lane departure avoidance, steering control, etc.) based on modern variable structure techniques (sliding mode observers, sliding mode observers based identification, sliding mode (SM) control).

The specific topics of interest within the scope of this special issue include:

- SM-based vehicles parameters and forces estimation
- SM-based control of automotive driver robot
- SM control of motor bicycle
- SM control of unicycle
- SM control of wheel slip
- SM-based observer of heavy vehicle
- Vehicle disturbance observation.

The special issue contains twelve papers that address various important issues related to vehicle dynamics and control of their trajectories using SM control and observation techniques. The papers are grouped into four clusters.

The first cluster of five papers deals with the applications of variable structure methods to control of vehicles.

This cluster starts with the paper ‘Application of variable-structure output feedback control to active front steering for understeer and oversteer conditions’, by Youssef Ghoneim, which describes an approach to the design of active front steering (AFS) based on variable-structure output feedback control (VSOFC) with integral action to enhance vehicle stability during understeer and oversteer conditions. The understeer and oversteer behaviour of the vehicle is obtained and the AFS control strategy based on the understeer and oversteer behaviour is changed so that the road wheel steering angle is in the ideal position to provide the intended steering angle. The control law ensures not only that the vehicle trajectory follows a desired reference trajectory but also that its convergence rate can be specified. The second paper, by Nestor Roqueiro, Enric Fossas-Colet and Marcelo Gaudenzi de Faria, is 'A sliding mode controlled three wheeled narrow vehicle'. A sliding mode controller for a narrow tilting three wheeled vehicle is developed. The vehicle is modelled as a dynamic system of order 18, with two inputs and two outputs. The designed trajectory control reckons vehicle stability limits and takes benefit of the bicycle model flatness. Tilting and speed controllers are designed in the sliding mode framework through analytical developments on the bicycle model and simulated in the full 18-order system.

The third paper, by Benedikt Alt, Elias Hermann and Ferdinand Svaricek, 'Second order sliding modes control for rope winch based automotive driver robot', develops a second order sliding modes control algorithm for position tracking of an in-vehicle driver robot. For this purpose, a recently developed rope winch based automotive driver robot is considered. Here, the distance between a brake, clutch or accelerator pedal and the ground of the driver's cab should follow a given reference value. Non-linear simulations and experimental results show the efficiency and the robustness properties of the proposed design approach.

Seibum B. Choi and Yunhyoung Hwang present the fourth paper of this cluster, 'Robust control of electronic wedge brake with adaptive pad friction estimation'. This paper suggests an adaptation scheme for robust control of the electronic wedge brake and estimation of the pad friction coefficient. The electronic wedge brake is highly energy-effective as it uses self-reinforcement. However, accordingly, it can be sensitive to parametric variation, particularly to the pad friction coefficient. The suggested scheme reduces the effect of the variation of the pad friction coefficient on system robustness and provides a way of estimating the friction coefficient. The simulation results verify the performance of suggested control scheme.

In the fifth paper 'Robust nested sliding mode integral control for anti-lock brake system', Juan Diego Sánchez Torres, Alexander Loukianov, Marcos Galicia and Jorge Rivera propose an integral nested sliding mode (SM) block control in order to control an anti-lock brake system (ABS) by employing integral SM and nested SM concepts. The aim is to achieve reference tracking for the slip rate, such that the friction between tyre and road surface is good enough to control the car. The closed-loop system is robust in the presence of matched and unmatched perturbations. A simulation study is carried out in order to show the performance of the proposed control strategy and the behaviour of the ABS under variations in the road friction.

The second cluster is devoted to slip control using sliding mode.

This cluster begins with the paper 'Improvements in vehicle handling and stability by a novel wheel slip coordination control scheme', by Xiujian Yang. A novel control scheme is developed in order to improve the vehicle handling and stability by coordinating the slips of the two wheels on the same side simultaneously. This scheme is a three-level structure consisting of the yaw moment controller (the first level), brake force distributor (the second level) and wheel slip regulator (the third level). The yaw moment controller is designed with a robust control approach that is optimal guaranteed cost control. The main contributions in this paper are the design of the second level, which is the brake force distributor and the third level, which is the wheel slip regulator. The brake force distributor distributes the desired brake forces to the two wheels on the same side properly and the wheel slip regulator is a sliding mode controller to track the desired slips generated by the brake force distributor. Single lane change manoeuvre and step input manoeuvre are examined by simulations carried out on an 8-degree-of-freedem (8-DOF) non-linear vehicle model.

The second paper of this cluster is 'Wheel slip control of road vehicles via switched second order sliding modes', by Antonella Ferrara and Mara Tanelli. This paper develops switched second order sliding mode control strategy in order to control wheel slip. Longitudinal wheel slip control is a crucial problem in automotive systems, as it is the basis for traction, braking and stability control. As slip dynamics are critically dependent on the vehicle speed, it is interesting to devise an adaptation of the controller parameters with respect to this variable. Specifically, slip dynamics get faster and thus more difficult to govern for the rider as speed decreases: hence, at low speed one would willingly lose tracking performance in exchange for increased safety. To achieve this, a novel switched second order sliding mode (S-SOSM) control strategy is proposed. It enhances the closed-loop performance and tunes it to the current working condition. Specifically, the S-SOSM control problem is formulated and discussed and its validity is assessed on a specific instance of the wheel slip control problem, namely the traction control of two-wheeled vehicles.

The third cluster is composed of papers related to sliding mode observer for estimation of contact forces and identification of disturbances.

The first paper of this cluster is 'Sliding mode based disturbance observer approaches for vehicle steering control', by Murat Demirci and Metin Gokasan. It is related to estimation of a disturbance on the control input channel by using past measurements instead of estimating the disturbance itself and is a very powerful method to improve vehicle motion dynamics. This study proposes two new disturbance observer approaches for vehicle steering control, which are based on sliding mode control theory. The controllers estimate the equivalent input extended-disturbance in the control input channel. The extended-disturbance includes modelling the parameter uncertainties of the vehicle, in addition to external yaw disturbances caused by side-wind, μ-split braking, etc. The aim of the disturbance observer based steering control is to force the vehicle to track a 2-DOF reference vehicle dynamics behaviour by estimating the equivalent input extended-disturbance, which is the front tyre steering correction angle for active steering system in this work. The sliding mode based disturbance observer approaches developed in this work are the first known applications to vehicle steering control. The performances of the proposed vehicle steering control systems have been compared with the performances of the inverse model based disturbance observer approach, which is a well-known disturbance observer method for motion control.

The second paper of this cluster is 'Heavy duty vehicle tyre forces estimation using variable gain sliding mode observer', by Omar Khemoudj, Hocine Imine and Mohamed Djemai. In this work, an original method for estimating heavy duty vehicle tyre forces is presented. The method is based on a variable gain sliding mode observer. The main on-board sensors are available through the CAN-bus of the vehicle, to which low-cost sensors are added. The approach is validated by comparing the estimated forces to those provided by the software vehicle dynamics simulator PROSPER.

The fourth and last cluster of this special issue is devoted to application of sliding mode in engine and transmission control.

The first paper, by L. He, Li Liang, Yu Liangyao and Song Jian, is 'Non-linear sliding mode control of switched systems on continuously variable transmission shifting'. The paper develops a method to control the speed ratio on continuously variable transmission (CVT) for CVT development. A non-linear sliding mode control law of switched systems is designed and employed to control the CVT shifting. Because the CVT shifting control system contains discontinuous characteristics, the Filippov solution with discontinuous right-hand side is used to design the sliding mode controller. Through the validation of simulation and on-board experiments, it can be concluded that the non-linear SMC law is a better candidate to control the CVT shifting.

The second paper, 'Condition monitoring of gasoline engine air intake system using second order sliding modes', by Qudrat Khan, Aamer Bhatti, Qadeer Ahmed and Mohsin Raza, presents a novel strategy for the condition monitoring of the air intake system of a gasoline engine. The aim is to detect and identify manifold leakages and throttle valve faults. These two faults directly affect air intake system performance, which results in poor engine efficiency. These two critical and non-measurable engine parameters are estimated using a mean value engine model and second order sliding mode observers based on a super-twisting algorithm. Nominal values of the estimated parameters are used to generate residuals, which are evaluated to classify system health. A successful validation of the proposed scheme is conducted to diagnose and classify the health status of an on board diagnostics version-II compliant commercial vehicle engine.

The third paper of this cluster, 'A new traction control system for the vehicle with automatic transmission', by Tong-Li Lu, Xiao-Wei Li and Jun-Wu Shi, presents a new traction control system based on integrated control of gear shifting and throttle for a vehicle with automatic transmission. By means of differential geometry theory, the slip control system with non-linearity and uncertainties is transformed into a linear one. Then the sliding mode control is introduced for the purpose of improving the robustness of the system. Furthermore, according to the dynamic programming, the optimal throttle opening and gear position are solved for the required driving torque.