Foreword

Jianbo Lu

Research and Advanced Engineering,
Ford Motor Company,
2101 Village Road,
Dearborn, MI 48150, USA
E-mail: jlu10@ford.com

Panagiotis Tsiotras

School of Aerospace Engineering,
Georgia Institute of Technology,
270 Ferst Drive,
Atlanta, GA 30332-0150, USA
E-mail: tsiotras@gatech.edu

Biographical notes: Jianbo Lu is a Technical Specialist at Research and Advanced Engineering of Ford Motor Company. He received his PhD in Aeronautics and Astronautics from Purdue University in 1997. He worked at Delphi Corp. from 1997 to 2000 and joined Ford Motor Company in 2000. His research interests include ground/space vehicle dynamics and control, control system integration, integrated sensing systems, semi-autonomous/autonomous systems and active safety. He holds more than 50 US patents, many of them were implemented in millions of vehicles. He is a recipient of the Henry Ford Technology Award. He currently serves as an Associate Editor for the *IFAC Journal of Control Engineering Practice* and the *IEEE Transactions on Control Systems Technology*, and he is in the editorial board of *International Journal of Vehicle Autonomous Systems*. He is a Senior Member of IEEE and a member of ASME and SAE.

Panagiotis Tsiotras is a Professor in the School of Aerospace Engineering at the Georgia Institute of Technology, and the Director of the Dynamics and Controls Systems Laboratory (DCSL) in the same department. He received his PhD in Aeronautics and Astronautics from Purdue University in 1993. He also holds Degrees in Mechanical Engineering and Mathematics. His research interests are in the dynamics and control of non-linear systems, optimal and robust control, and ground, space and aerial vehicle autonomy. He is a recipient of the NSF CAREER Award (1996), and the President's Award for Excellence in Research from the Sigma Xi Society. He is a current or past member of the Editorial Boards of the *AIAA Journal of Guidance, Control, and Dynamics*, the *IEEE Transactions on Automatic Control*, the *IEEE Control Systems Magazine* and the *Dynamics and Control: An International Journal*. He is a Fellow of AIAA and a Senior Member of IEEE.

Current technological advances in the area of embedded sensing and control are opening the possibility for completely accident-free driving of passenger vehicles. This topic has been discussed by various automotive manufacturers and government agencies around the world. To achieve this goal, increased levels of autonomy will be required onboard the vehicle, as demonstrated during the recent DARPA Grand Challenge competitions. Full autonomy could be conducted in long duration operation and continuous unsupervised driverless control, or in short-time intervals, in an on-demand basis. Both continuous and on-demand autonomy can be applied to achieve safe driving of ground vehicles.

Besides full autonomy, which is probably more appropriate for robotic vehicles, the co-existence of the electronic controls and the human control is, perhaps, a more suitable and near-term goal for passenger vehicles driven by a human operator. In this case, the control operates in a semi-autonomous mode, which means that the driver is still in control, and the various electronic controls try to assist the driver to achieve his or her driving goals, by interpreting his or her intention, correcting them and intervening, if and when it is necessary, to enhance the vehicle response and handling characteristics. For instance, a variety of electronic control systems including Anti-lock Brake System (ABS), Traction Control System (TCS), Electronic Stability Control (ESC), Roll Stability Control (RSC), etc., can already be found in almost all vehicles on the road nowadays; these electronic control systems operate on-demand, and they safeguard and enhance the performance of the vehicle by providing a natural co-existence of the driver-in-the-loop and the electronics-in-the-loop.

Eliminating accidents completely, however, will require control systems incorporating increased levels of autonomy and intelligence, along with immunity to unforeseen circumstances. Designing the next level of algorithms for accident-free vehicles provides new challenges to the automotive, controls, perception and computer science communities.

In this special issue, we showcase nine papers covering a wide spectrum of recent advances in autonomous and semi-autonomous control for safe driving of ground vehicles. The papers by Bianchi et al. (2010) and Ghoneim (2010) study the integration of various chassis controls to achieve safe driving through vehicle stability controls. Specifically, Bianchi et al. (2010) consider an integrated chassis control problem for Active Front Steering (AFS) and rear torque vectoring with vehicle stability and handling improvement using an adaptive feedback linearisation scheme; Ghoneim (2010) considers the integration of the ESC system with an AFS system. A supervisory controller module is proposed that can detect heavy understeer tendency of a vehicle and intervene with the correct distribution of control action between ESC and AFS. The papers by Gáspár et al. (2010) and Chiu et al. (2010) both study the vehicle rollover control problem. The paper by Gáspár et al. (2010) uses active brake control for reducing the rollover risk of heavy vehicles using a control design based on a linear parameter varying model of yaw-roll dynamics. The paper by Tamaddoni et al. (2010) applies recent results from robust control to rollover prevention to design robust controllers to guarantee that the peak values of the performance outputs do not exceed certain values. The papers by Tamaddoni et al. (2010) and Anderson et al. (2010) consider the semi-autonomous control problem where both electronic controls and human co-exist. In particular, Tamaddoni et al. (2010) deal with human-in-the-loop issues when developing active safety systems. The effect of driver intervention and its interaction with the vehicle controller is treated from a game theoretic point of view.

One player (the driver) uses steering, while the other player (the vehicle stability controller) uses compensated yaw moment to maintain stability, and their coordination is treated as a two-player Nash equilibrium problem. The paper by Anderson et al. (2010) tries to answer the question on the 'optimal' level of control system intervention to honour driver intent, while maintaining collision-free trajectories. The driver's control input and a delicate balance between level and frequency of intervention are required for a seamless integration of an active safety system. A holistic architecture for the semi-autonomous control ('driver-assist') of vehicles in hazard avoidance scenarios is proposed where trajectory planning and tracking are addressed using an MPC-based framework. The paper by Velenis et al. (2010) studies steady-state cornering conditions for a single-track vehicle without imposing restrictive conditions on the tyre slip. Such conditions may arise under extreme manoeuvring in the face of an impeding emergency. For each steady-state cornering condition, the authors calculate the corresponding tyre friction forces at the front and rear tyres, as well as the required front steering angle and front and rear wheel slip ratios, to maintain constant velocity, turning rate and vehicle sideslip angle. A sliding-mode control scheme stabilising steady-state cornering conditions is proposed, which uses only longitudinal (i.e., wheel acceleration/braking) control inputs. The paper by Zhou et al. (2010) addresses vehicle dynamics control in response to exogenous impulsive disturbances owing to an initial light collision with another vehicle. It takes on the issue of active safety control strategies to mitigate post-collision vehicle response. To counteract the post-impact loss of control, a driver-assist control mechanism using differential braking, similar to ESC, is proposed. The scheme activates and prioritises the braking forces at the tyres to quickly attenuate undesired vehicle motions. The control objective is to attenuate the vehicle's sideslip, yaw and roll rate as soon as an impulsive disturbance is detected and a supervisory MPC-based strategy is proposed. Finally, the paper by Yang and Zheng (2010) studies the problem of vehicle lateral control in urban environments. An expert fuzzy controller with the strategy of two look-ahead points is proposed to gain good control performance under all driving tasks, such as lane following and lane changing with a small steering angle of the front wheel at high speeds, and cornering with a large steering angle at lower speeds.

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