Introduction to the Special Issue on Applications of Mechatronic and Embedded Systems (MESA) in ITS

EMBEDDED systems result from the integration between mechanical and electronic components (hardware) and the information-driven functions (software). Embedded systems play a key role in the development of mechatronic systems, which involves finding an optimal balance between the basic mechanical structure, sensor and actuators, automatic digital information processing and control.

In the field of Intelligent Transportation Systems, mechatronic and embedded systems have been applied in many areas, from Automatic Vehicle Localization (AVL) to trajectory planning, from Human Machine Interface (HMI) to Driver Assistance Systems (DAS), from automotive systems to autonomous vehicles, etc.

This special issue provides a collection of high-quality papers presenting technologies, methodologies and, particularly, applications of mechatronic and embedded systems in various aspects of Intelligent Transportation Systems, including both established and state-of-the-art solutions. It originated from the symposium of "Mechatronic & Embedded Technologies in Intelligent Transportation Systems" at the 12th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications - MESA 2016 held in Auckland, New Zealand, August 29-31, 2016, a conference co-sponsored by both the IEEE Intelligent Transportation System Society and the ASME Design Engineering Division. However, the special issue was opened to the entire international research community and indeed the greater part of the submitted papers were out of that conference.

We received twenty-three contributions. All papers were subjected to the regular reviewing process of the IEEE Transactions on Intelligent Transportation Systems journal, i.e., papers were reviewed by at least three international reviewers with expertise in the specific field. During the multi-stage reviewing process, eleven papers were rejected and one was withdrawn after the first reviewing stage. To meet planned publication schedule, this special issue includes the ten papers that have been accepted, while one additional paper is still under review process.

As regard the main topics addressed by the papers in this special issue, the first group of four papers is related to DAS, starting from a framework for developing a supervisor that properly coordinates multiple DAS and proceeding with tasks concerning fleets of vehicles, from the analysis of plant and string stability in connected cruise control to a probabilistic multiple vehicle grouping framework to track groups of vehicles and eco-DAS for improving fuel-economy. The second group of four papers is related to specific tasks for autonomous vehicles, from vehicle localization and tracking to trajectory planning and the more technical Differential Driver Assistance Steering (DDAS) systems. The remaining papers deal with two particular tasks, namely the integration of human factors in Car-Following (CF) models and a mechatronic system to help visually impaired users during walking and running.

Given the growing number of DAS that are more and more coupled and interacting with each other to achieve increasingly high-level, intelligent assistance and autonomy, the proper coordination of the different subsystems becomes an increasingly complex and safety-critical task. With the need to ensure no deadlock and livelock situations during operation, Tim Korssen *et al.* propose a new model-based system design framework for developing higher-level supervisor layers that properly coordinate multiple lower-level DAS. The paper presents and discusses a case study with a proof-of concept implementation, including requirement specifications and discrete-event models, of a supervisor modeled for Cruise Control and Adaptive Cruise Control for a modern passenger vehicle.

In the coming scenario of self-driving cars, where advanced DAS are expected to interact with other traffic participants, Tamas Molnar *et al.* investigate the flow of a group of vehicles travelling on a single lane and using connected cruise control to regulate their longitudinal motion based on data received from other vehicles via wireless vehicle-to-vehicle communication. They examine both the "plant stability" related to the safety and collision avoidance between vehicles, and the "string stability" to prevent the formation of stop-and-go traffic jams while ensuring smooth traffic flow. They propose two feedback predictor strategies to solve the problems related to the loss of data packages and sample delays in the control loop. The first strategy estimates the velocity and the distance of the vehicles by using the vehicles' earlier data packets; the second strategy predicts the state of the system in order to compensate the processing delay.

Qian Wang and Beshah Ayalew depict a probabilistic framework to estimate the formation and evolution of object vehicle groups and the membership for individual object vehicles forming the groups. The method takes into account the temporal variation of each vehicle and uses a Bayesian estimation approach to estimate the states of the individual vehicles with uncertainties due to sensor imperfections and other disturbances acting on the vehicles. Groups of vehicles are tracked by considering their geometric shape information

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and by evaluating the closeness of the individual vehicles in both their positions and velocities. The authors also include a way to generalize the states of each group, which can reduce the tracking computational cost, thus improving the manageability of the traffic.

Hongjie Ma *et al.* propose an evaluation model for different driving styles, generated using a decision tree, to be used by a learning path planning algorithm to assist existing rule-based echo-driving systems in improving fuel-economy and, consequently, in reducing the operational cost of running a fleet of vehicles, such as city buses. Simulation results, based on vehicle and engine physical models, show how the proposed evaluation model, a pure data model based on machine learning, can be used as an alternative to the physical model for the guidance of eco-driving.

In the context of autonomous driving in public roads, Rafael Vivacqua *et al.* propose an interesting approach, based on low-cost sensors and with the software able to run on a low-power embedded architecture, for an accurate vehicle localization within the range of a few centimetres. Their approach exploits a short-range visual lane marking detector and a dead reckoning system to construct a registry of the detected back lane markings corresponding to the last 240 m driven. This information is used to search in the map the most similar section, to determine the vehicle localization in the map reference. Test results show that the accuracy obtained is sufficiently high to keep the autonomous vehicle at the center of the lane while moving along a predetermined trajectory.

Dongchul Kim *et al.* propose an algorithm for the tracking of moving vehicles that is robust under appearance changes, as validated in real traffic experiments. By using 2D point clouds from a laser scanner, which represent only the surface of an object facing the sensor, changes over time in the appearance of an object usually produce unexpected tracking errors. On the contrary, their method, based on L-shape models, tracks the corner point (and its two lines) closest to the laser scanner on the ego-vehicle and, when a view point change is detected, handles a corner point/model switching to mitigate the effect of appearance changes. The tracking is performed by two Kalman filters, one for 2D position, velocity and acceleration, and another for the shape of the feature (line length, orientation and yaw rate).

Kichun Jo *et al.* integrate different methodologies to decompose the complex problem of autonomous urban driving into simpler sub-problems. The proposed method combines a 'coarse' sampling-based planning strategy with a 'finer' optimization approach with real-time performance. The first step generates a coarse maneuver for the autonomous vehicle dealing with other traffic participants, traffic control devices and driving rules. For each candidate path, an optimal speed planning is used to extend the search in the space-time domain correctly handling other moving vehicles. The second step refines the coarse behavioural trajectory to a dynamically-feasible motion trajectory taking into account dynamic limits, driving comfort and fine-checked collision avoidance.

Chuan Hu *et al.* consider Differential Driver Assistance Steering (DDAS) systems and propose an integral sliding mode control (ISMC) approach for the yaw stabilization of in-wheel-motor driven (IWMD) electric vehicles when the regular steering system entirely breaks down. In particular, the control objective is to deal with the unknown mismatched disturbances and to restrain overshoots and to remove steady-state errors considering the tire force saturations.

While most of traditional mathematical Car-Following (CF) models/simulators capture vehicle dynamics without considering human factors, such as driver distraction, Jin Ro *et al.* propose a formal model to integrate existing CF models with three human factors: a variable reaction delay (usually modelled as a constant), temporal anticipation on the leader's acceleration, and estimation error on the position/distance of the leader vehicle. The adoption of Hybrid Input Output Automata (HIOA) allows to model rigorously the hybrid, i.e., discrete and continuous, behavior of the human CF model. The model is evaluated and validated using experimental data by an implementation in Simulink, which shows that the following vehicle position is computed more accurately than in conventional CF models.

Adriano Mancini *et al.* present a mechatronic embedded system that is capable of improving the quality of life for the visually impaired by allowing them for sport activities, like jogging and running. The wearable system is composed of three elements: a small camera, an embedded board/computer and a haptic device, namely two gloves equipped with vibration motors that drive the user to the right direction. The technical information of the physical system (hardware and software chosen by the authors) is described in detail. An important content of the paper is how vision is interfaced with the haptic device by means of a pure pursuit controller and a fuzzy controller. In fact, the main target of the approach was a computer vision algorithm capable of coping with different environment conditions and under direct sunlight but requiring a low computational power, which is crucial to guarantee a very low latency even on a low-power embedded hardware.

Finally, we would like to thank all researchers having submitted papers to this special issue, i.e., for choosing T-ITS journal as a venue for their work. We would also like to express our gratitude to the reviewers and the members of the editorial team for their help and support in producing this special issue.

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APPENDIX
RELATED WORK

1) T. Korssen, V. Dolk, J. van de Mortel-Fronczak, M. Reniers, and M. Heemels, "Systematic model-based design and implementation of supervisors for advanced driver assistance systems," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 2, Feb. 2018.
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4) H. Ma, H. Xie, and D. Brown, "Eco-driving assistance system for a manual transmission bus based on machine learning," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 2, Feb. 2018.
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7) W. Lim, S. Lee, M. Sunwoo, and K. Jo, "Hierarchical trajectory planning of an autonomous car based on the integration of a sampling and an optimization method," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 2, Feb. 2018.
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9) J. W. Ro, P. S. Roop, A. Malik, and P. Ranjitkar, "A formal approach for modeling and simulation of human car-following behavior," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 2, Feb. 2018.
10) A. Mancini, E. Frontoni, and P. Zingaretti, "Mechatronic system to help visually impaired users during walking and running," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 2, Feb. 2018.

Massimo Bertozzi received the Ph.D. degree in information technologies from the University of Parma, Parma, Italy. He is currently an Associate Professor of computer engineering with the Dipartimento di Ingegneria e Architettura, University of Parma. He has been involved in different research projects to test intelligent vehicles, such as: MilleMiglia in Automatico in 1998, Grand Challenges in 2004 and 2005, Urban Challenge in 2007, and the VisLab Intercontinental Autonomous Challenge in 2010. His research interests include the application of image processing to vehicle guidance and the optimization of machine code.

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