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Editorial

Analysis and Synthesis of Coordinated Control Systems for Automated Road Vehicles

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Through the automation of road vehicles, several smart actuators have been developed, with which various automated and autonomous functionalities can be performed. For example, the maneuvering of vehicles can be achieved through automated steering, torque vectoring, differential braking, and variable-geometry suspension. Despite the similarities in these functionalities, the operation capabilities and cost aspects of each intervention can be different.

The goal of the current research in this field is to propose analysis and synthesis methods, with which safe and energy-optimal coordination strategies of automated vehicle-control systems can be achieved. This research goal poses various control–theoretical challenges, e.g., the handling of nonlinearities, the formulation of uncertainties, and the assessment of the performance issues in automated systems. Nevertheless, the conventional reconfigurable, robust, parameter-varying, and nonlinear methods provide a starting point for finding solutions for these problems. Moreover, through the novel data-driven and learning-based approaches, promising results in the field of automated vehicle control have be achieved.

The coordination of vehicle-control systems is incorporated at a high level, which goes beyond the problem of coordination at the vehicle's level. The developed vehicle-control solutions must guarantee its cooperation with human interventions—i.e., during the operation of partially automated systems, the intentions and interventions of the driver must be considered. Furthermore, the integration of automated vehicles in an intelligent transportation system provides novel performance requirements on the vehicle level. Thus, the coordination of vehicle-control systems must be carried out to improve the performances on both local and global levels simultaneously. The goal of this Special Issue is to provide insight into new approaches in coordination which consider the high-level context.

In this Special Issue, various solutions on the existing problems and challenges have been provided, including three papers regarding the synthesis methods for vehicle-level control. The problems of control design for the coordination of vehicle-control systems, especially four-wheel steering, electronic stability control (ESC), and a torque vectoring device (TVD) have been presented in the work of [1]. The key of the proposed solution is to consider the situation in which front-lateral tire force is limited to a maximum value, i.e., the yaw moment cannot be generated. This shortfall can be compensated for through the coordination of rear-wheel steering, ESC, and TVD control interventions. Two further papers have focused on the use of data for vehicle-control synthesis. The problem of finding an optimal coordination approach of lateral-control systems, such as front-wheel steering and TVD, was approached in [2]. The motivation of the research is to improve the performance level of the coordinated system more effectively than the conventional-model-based reconfigurable solutions. The paper provides a control design solution within the framework of linear-parameter-varying (LPV) systems. The designed vehicle dynamic control systems have been coordinated through a reinforcement-learning-based (RL) approach. Using data within the vehicle control design process on the level of autonomous vehicle modeling is another approach. In [3], a neural-network-based model-matching process was developed, the aim of which is to handle the nonlinear characteristics of vehicle dynamics.

Thus, a novel robust control algorithm is proposed, which exploits the advantages of both the classical control and machine-learning-based methods. The contribution of the paper is an enhanced modeling and synthesis method, which results in an improvement in the vehicle's performance level, e.g., its tracking capabilities.

Analysis and synthesis methods regarding the high-level context, especially transportation, have also been provided in this Special Issue. A current challenge is to examine the impact of automated and electric vehicles (EVs) on traffic flow characteristics, and the influence of traffic flow (e.g., volume, average speed) on individual vehicle control. The authors of [4] provide a modeling process on the energy consumption of electric vehicles, considering the impact of traffic flow based on data-driven analyses. Experimental vehicular data were extracted from traffic (floating-car data and probe-vehicle data) and energy-consumption data were measured for equipped EVs performing trips in an Italian subregional area. A process for the systematic calibration of the model was developed, which allows for the parameters related to energy consumption and energy recovered to be updated in terms of EVs—findings were obtained from data observed in real conditions. Another work focused on formulating a model for the collapse of tunnels under constructions [5]. During the formulation of the model, the impact of vehicle sizes was considered, leading to a scheduled model. Given the influence of different special road conditions on the speeds of differently sized vehicles, a multi-objective model was formed; the model contains two stages and was presented to make decisions in rescue vehicle scheduling. With the priority of saving human lives, the first-stage objective of the model is to reduce the arrival time, while the objective of the second stage includes addressing the level of unmet demands and scheduling costs.

The presented papers provide an appropriate basis for the continuation of research in the field of coordinated control. Various open questions have been asked in this Special issue, e.g., addressing the acceptability and quality-oriented analysis of data from vehicle-to-vehicle communication or infrastructure-to-vehicle communications. Since the measured and transmitted data significantly influence the effectiveness and the operation of the control, preliminary analysis of the data in terms of safety issues must be carried out. Another open problem is to find systematic analysis methods, with which the provided methods can be validated from the viewpoint of safety performances. Although scenario-based simulations and test evaluations can be efficient for conventional-model-based control systems, the safety validation of learning-based control solutions is a challenge.

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