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Letter from the Special Issue Editors

Special Issue on Robust, Safe, and Secure Implementation of Connected and Automated Vehicles' Functional Software Design and Architecture: Facilitating a Reliable, Feasible, and Comfortable Future Mobility

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Public discussions on the wide-scale implementation of connected and autonomous vehicles (CAVs) mostly rely on the media. As such, what is usually understood about "autonomous vehicle technology" by the general society is not necessarily equal to the current stage of the industrial production of "autonomous vehicles" in a similar timeline. To elaborate, society tends to have a misunderstanding about the technology where the autonomous vehicle (AV) is commonly perceived as a "vehicle with the highest level of automation" [1]. In reality, to enable a feasible, market-wide deployment of the technology, CAV technology, as a product, should be released to the market incrementally in a technologically realistic timeline. This unrealistic expectation and misunderstanding by the public, due to the aforementioned misapprehensions, subsequently puts impractical business expectations on engineering and development teams. Without proper regulation and safety consideration, this could be hazardous.

One of the reasons why CAVs stimulate discussion is because it is part of the future mobility concept. At a high level, future mobility can be described as the future ecosystem of automotive transportation and mobility. The concept predicts that in the future, vehicles will be "Autonomous, Connected, Electric, and Shared" (ACES) [2]. However, for ACES to happen on a wide scale, it needs to receive an acceptable measure of user approval. To increase public acceptance of the technology, safety and comfort criteria should be focused on the technology design. To deliver the four ACES elements, CAVs remain challenging because, in the time period of the automated driving experience, there has been no or limited involvement of human drivers. To facilitate a reliable, feasible, and comfortable future mobility that is accepted by the public, CAVs should possess a high-quality and safe design and implementation; however, since CAVs' product development is still considered a new field, discussions that focus on quality and safety topics are still limited and have not yet widely reached the practitioners' community.

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Thus the aim of this special issue for the *SAE International Journal of Connected and Automated Vehicles* is to discuss robust, safe, and secure implementations and design on CAVs. Etymologically, a robust performance can be described as something strong, whereas safe indicates the state of being risk-free, while reliability is synonymous with dependability. As such, this special issue discusses and advances these topics to yield performance and quality at all times during the automated driving state of an automated vehicle, from the perspective of design and implementation. Because CAVs promote the total absence of human drivers in the driving loop while performing in uncertain and dynamic road scenarios, regular discussions on the topics that this special issue highlights should be addressed.

This special issue will benefit practitioners, researchers, and industry experts. It is also hoped to indirectly educate multidisciplinary experts and the public and give a glimpse of the complexity and severity of the topics. The guest editors consist of experienced researchers from automotive sectors (CAV, active safety, and collision avoidance). Collectively, the guest editors firmly believe that a rise in awareness on these topics can subsequently motivate similar works, which can, in turn, yield a safer CAV technology and eventually facilitate a reliable, feasible, and comfortable future mobility.

The special issue consists of ten scientific and technical articles. The contributors come from various backgrounds and include industry experts, regulatory bodies, and researchers from academia. The articles are organized into three different sections.

The first section "Robust, Safe, and Secure Implementation of Connected and Automated Vehicles: System Engineering Discussions" comprises three articles.

The first article "Towards a Formal Model for Safe and Scalable Automated Vehicle Decision Making: A Brief Survey on Responsibility-Sensitive Safety (RSS)" by Maria Soledad Elli et al. provides a survey of the RSS model and its importance on AV safety topics. RSS allows a minimum safety requirements definition process based on several criteria, weighing the safety and practicalities of automated driving vehicles' use cases.

The second article "Model-Based Systemic Hazard Analysis Approach for Connected and Autonomous Vehicles and Case Study Application in Automatic Emergency Braking System" by Duan Jianyu et al. proposes a model-based hazard analysis method utilizing Systems Theory Process Analysis and Model-Based Systems Engineering approaches to alleviate the ISO 26262 and SOTIF-related compliance process. This is done by proposing a collaboration between the system designer and safety analyzer, which subsequently has the potential to expedite the system development iteration process.

Juozas Vaicenavicius et al. in their work "Self-Driving Car Safety Quantification via Component-Level Analysis" present a rigorous modular statistical approach for arguing safety or its insufficiency of an AV through a concrete illustrative example. The article concludes that a separate perception system and operational design domain statistical analyses can be used to prove or disprove safety at the vehicle level.

The next section "Robust, Safe, and Secure Implementation of Connected and Automated Vehicles: Safer Algorithm and Software Frameworks" is comprised of four articles.

The first article in the section "Tracking and Fusion of Multiple Detections for Multi-Target Multi-Sensor Tracking Applications in Urban Traffic" by Andinet Negash Hunde proposes a hybrid approach that combines a clustering technique (such as DBSCAN) to alleviate the computational complexity and employs multiple detection tracking schemes that admit multiplicity of the target detections. The proposed systems are experimentally validated, which can contribute to the detection modules of CAVs.

Lin Zhang et al. discuss the control and handling performance of an AV in the next article, "Torque-Vectoring Control of Autonomous Vehicles Considering Optimization of Vehicle Handling Characteristics." The work proposes a hierarchical scheme of the Torque-Vectoring Controller, whose key parameters affecting the control objective are optimized from the human-vehicle closed-loop simulation test. From the results, the standard deviation of the state tracking error performance is shown to be reduced by at least 49.1% compared with other types of strategies, such as first-order sliding mode control and PID.

The next article "An Optimal Controller Synthesis for Longitudinal Control of Platoons with Communication Scenarios in Urban Environments and Highways" by Anuj Abraham et al. is on CAV use case in highway and urban environments. The contribution of this work is principally toward the design of a platoon controller that allows a long Heavy Goods Vehicle (HGV) platoon to execute safety-critical maneuvers such as split and merge under communication constraints. The results show that the controller can maintain the desired constant distance and time gap. The findings will be beneficial for the CAV use case in highway and urban environments.

Selim Solmaz et al., in their article "Compensation of Sensor and Actuator Imperfections for Lane Keeping Control Using a Kalman Filter Predictor," present a problem that originates from a control design case study for lateral control of automated vehicles. A lane-keeping control algorithm was developed and tested in a simulation environment and was planned to be implemented in a test vehicle. The approach is described using simulation results and verified with results from a test vehicle in real driving conditions.

The final section is entitled "Robust, Safe, and Secure Implementation of Connected and Automated Vehicles: Testing, Validation, and Use Case" and includes three articles.

The first article of the section "Connected and Automated Driving in Snowy and Icy Conditions—Results of Four Field-Testing Activities Carried Out in Finland" by Ilkka Antti Kotilainen et al. summarizes work on comprehensive extreme conditions of testing of CAVs in Finland. Some of the tests were done above the Arctic Circle, and the findings will be beneficial for CAV researchers, particularly with regard to CAV performance in those areas.

In "Identification of Test Scenarios for Autonomous Vehicles Using Fatal Accident Data," Mustafa Ilhan Akbas et al. propose an AV test scenario generation system that creates abstract test scenarios using historical fatal accident data. The authors conclude that the proposed focused strategy will accelerate the identification of faults in AV systems by complementing the current available testing methods.

"Hybrid Testing: A Vehicle-in-the-Loop Testing Method for the Development of Automated Driving Functions" is the final article of this special issue. Selim Solmaz et al. describe a novel test methodology called "Hybrid Testing" that was developed in the scope of the EU-H2020 project INFRAMIX, which enables the evaluation of a real vehicle in a virtual scenario in an enclosed proving ground with simulated traffic components and sensor signals, thereby combining the benefits of simulation and real-life testing. The authors show the utilization of this novel testing methodology for the evaluation of a trajectory planning algorithm to demonstrate its working principles and benefits.

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Find the online special issue here.

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