Editorial: Driving into Future with Reliable, Secure, Efficient and Intelligent MetaVehicles

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Welcome to the sixth issue of the IEEE/CAA Journal of Automatica Sinica (JAS) in 2023! In the first issue in 2023, I briefly discussed about MetaVehicles, a technological expression of intelligent vehicles, robotics, AI, blockchain, knowledge automation, networking and communication [1]. As the concept of the Metaverse continues to evolve and expand, the range of vehicle entities is diversely enlarged, including passenger vehicles, heavy duty vehicles, rail vehicles, marine vehicles, aerial vehicles, and other types of transportation. The development and use of MetaVehicles are likely to become more sophisticated. Therefore, from a systems and control perspective, new methods of control, estimation and optimization should be developed to achieve the improved vehicular control system stability and reliability in the physical space, guaranteed security in the cyber space, promising efficiency in both communication and control layers, and enhanced intelligence in both control and decision-making processes. Achieving these objectives requires advanced vehicular control and communication systems that can detect and respond to physical faults/failures and cyber threats, optimize control and communication performance, provide comfortable and convenient driving experiences, minimize emissions, and interact with a wide range of other vehicles and infrastructure.

At IEEE/CAA JAS, we welcome and value the control, estimation and optimization contributions towards reliable, secure, efficient and intelligent MetaVehicles. In this editorial, I collected twenty articles published in IEEE/CAA JAS in the recent three years, relevant to this important topic. Specifically, I classify them into the following five groups.

1) Reliability Under Sensor and Actuator Faults: Sensor faults and actuator faults are common issues that can affect the stability, performance and safety of a vehicle. It is indispensable to address sensor and actuator faults promptly as they can result in a range of issues, such as poor performance, reduced fuel efficiency, and even safety concerns of a vehicle. Regular maintenance and inspection can help to identify and prevent these faults, while advanced diagnostics and control techniques are still demanded to identify and resolve faults quickly and effectively. For example, a distributed set-membership cooperative estimation technique is developed [2] to jointly estimate the lateral dynamical state (i.e., the yaw rate and sideslip angle) of an autonomous ground vehicle when sensor faults and unknown external disturbance and measurement noises co-exist. An adaptive anti-disturbance and fault-tolerant control technique is devised [3] for a group of multi-rotor unmanned aerial vehicles subject to simultaneous output dead-zones, external disturbances and actuator faults.

2) Security Against Cyber and Physical Attacks: Connected and automated vehicles (CAVs) are vehicles equipped with advanced communication technologies that allow them to communicate with other vehicles and roadside infrastructure. This connectivity enables CAVs to operate more efficiently, provide better safety features, and deliver enhanced user experiences. However, it also introduces new security challenges. Several security measures have been developed, such as encryption, authentication, and intrusion detection. However, these measures do not fully exploit the physics and dynamical behavior of vehicular control systems. It is thus significant to develop advanced control techniques that can secure CAVs from attacks. For example, a resilient and safe distributed longitudinal platooning control method is proposed [4] for CAVs subject to intermittent denial-of-service (DoS) attacks that disrupt vehicle-to-vehicle communications. The method is capable to guarantee simultaneously the desired platoon stability and resilience as well as anticipated platoon safety and scalability regardless of DoS attacks. The problem of distributed secure platooning control is addressed [5] for CAVs under a class of replay attacks, where the desired control signal to each CAV is maliciously altered by attackers via recording and replaying some outdated control commands.

3) Efficiency in Communication Resource and Control Energy Consumption: Communication resource efficiency and control efficiency are both important aspects of modern vehicle design and implementation. More specifically, communication resource efficiency refers to an efficient use of precious communication resources in in-vehicle communication network (e.g., controller area network), vehicle-to-vehicle communication network and vehicle-to-infrastructure communication network, which allow vehicles to share information within the vehicle, with each other and with roadside infrastructure. The importance of vehicle communication resource efficiency lies in its ability to improve safety, traffic efficiency, and user experience, as well as enable advanced vehicle features. On the other hand, control efficiency refers to the ability of a vehicle to control its motion and respond to driver inputs with optimal energy consumption and/or improved fuel efficiency. More efficient vehicles that consume less energy and have a smaller environmental footprint then are possible via optimizing engine and transmission operation, regenerative braking, hybrid and electric vehicle control, and driving style. For example, event-triggered control techniques are

Citation: Q.-L. Han, "Editorial: Driving into future with reliable, secure, efficient and intelligent metavehicles," *IEEE/CAA J. Autom. Sinica*, vol. 10, no. 6, pp. 1355–1356, Jun. 2023.

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Digital Object Identifier 10.1109/JAS.2023.123621

employed to achieve communication resource-efficient active suspension control of in-wheel-motor driven electric vehicles [6] and communication resource-efficient platooning control of CAVs [7], [8]. Focusing on vehicle fuel consumption, an eco-route planner that guarantees the minimum fuel consumption and the requested arrival time is developed [9] for heavy duty vehicles. The case study therein shows both improved fuel consumption and CO_2 emission. An optimal winner-take-all control strategy is presented [10] to accomplish target tracking and cooperative competition of multiple unmanned aerial vehicles. The case studies demonstrate that high precision, strong stability, chattering avoidance, minimum control energy can be ensured. Route-preview-based real-time control strategies are proposed [11] for plug-in hybrid electric vehicle energy management to achieve fuel minimization.

4) Intelligence via Learning: Intelligence is an important aspect of modern vehicle control systems. By incorporating machine learning, neural networks, fuzzy logic, reinforcement learning, and other form of artificial intelligence, vehicle control systems can achieve improved performance, optimal vehicle operation, and enhanced safety. For example, neural networks are used in vehicle control systems to compensate the aerodynamic effects of multi-rotor unmanned aerial vehicles [12] and to learn the unknown nonlinearity in each vehicle's dynamics [13]. Fuzzy logic control is applied to adaptive cruise following vehicle systems to simulate the driver's operating habits [14]. A transfer learning pigeon-inspired swarm intelligence optimization algorithm is proposed to realize autonomous maneuvering of unmanned combat aerial vehicles in dogfight engagements [15].

5) Relevant Surveys: Before ending this Editorial, I would like to briefly introduce six comprehensive surveys highly relevant to the important topic discussed above. In the first survey [16], the latest swarm intelligence algorithms used for solving various optimization problems are reviewed in detail with their main functions and strengths highlighted. The next two surveys [17] and [18] cover the recent advances in cooperation of underwater multi-robot systems and motion control of underwater gliding robots, respectively. In [19], the existing classic and advanced control methods for unmanned aerial vehicles are reviewed. The fifth survey [20] provides an overview of the recent developments in learning-based optimization for vehicle routing. The existing learning-based optimization approaches are classified into end-to-end approaches and step-by-step approaches. In the last survey [21], the state-of-the-art model predictive control (MPC) techniques used for motion planning and control of autonomous marine vehicles, including remotely operated vehicles, autonomous underwater vehicles, and autonomous surface vehicles, are systematically evaluated. Some promising future directions for planning and control, such as data-driven MPC, MPC as a service, resilient and secure MPC, are also elaborated.

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