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Letter from the Special Issue Editors

Special Issue on Advanced Learning and Data Analytics Methods for Electrified Vehicles

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Driven by the motivation of environmental protection and long-term energy sustainability, the automotive industry is now experiencing a revolution from internal combustion engine vehicles to electrified vehicles. On one hand, mainstream electrified vehicles companies like Tesla, Rivan, NIO, and Lucid Motors are heavily invested. On the other hand, conventional original equipment manufacturers like Toyota, Volkswagen, and Ford are accelerating their new electrified vehicle releases to maintain the market share of their brands in the global market.

Artificial intelligence technologies have been booming since the early 2010s. First shining at image processing, artificial intelligence technologies are then applied to various engineering applications including natural language processing, autonomous driving, new medicine/material design, disease diagnosis, financing, etc. The advancement of computation hardware also assists the boom. Advanced learning and data analytics play key roles in the artificial intelligence domain. They are utilized in raw data processing, feature engineering, complex system modeling, iterative learning, and optimal control.

When applied to electrified vehicles, advanced learning and data analytics can be used in energy management, energy system state estimation, vehicle/road condition modeling, environmental perception, path planning/following, vehicle diagnostics, etc. Compared with conventional modeling and control methods, advanced learning and data analytics methods are less dependent on vehicle system physics and experts, which make their development process more automatic. Therefore, they are time and cost effective.

This special issue contains seven articles, focusing on energy management, energy system state estimation, and vehicle/road condition modeling. To be more specific, reinforcement learning and supervised learning are applied to electrified vehicles under the topic of energy management. In terms of vehicle and road condition modeling, the battery is modeled with neural networks, and vehicle driving cycle velocity is modeled with the Markov decision process. On the topic of energy system estimation, battery state-of-charge and state-of-health estimates are studied.

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For electrified vehicles, energy management strategy plays a critical role. It manages the operations of multiple energy resources, including battery, fuel cell, supercapacitor, internal combustion engines, etc., and determines the power flow from/to different energy resources. The first three articles investigate data-driven methods related to energy management strategies. Arash Khalatbarisoltani et al. propose a decentralized reinforcement learning framework for designing an energy management strategy for a heavy-duty hybrid proton-exchange membrane fuel cell vehicle, which includes two parallel fuel cell systems and a battery system. This work is motivated by the higher modularity (plug and play) and reliability of the decentralized framework when compared to a centralized framework. Simulation and experimental tests are conducted to validate the fast convergence speed and great optimization performance of the proposed decentralized framework. In the second article, Zhengyu Yao et al. applied a model-free off-policy twin delayed deep deterministic policy gradient method (TD3) as the energy management strategy for a 48V mild hybrid electric vehicle. The TD3 strategy is evaluated in a simulation environment, and promising results are reported in comparison with a deep deterministic policy gradient strategy.

Thanks to the fast-growing connected and automated vehicle technologies, more information and flexibility are available to improve the energy management of electrified vehicles. In the third article, Haojie Zhu et al. conducted an energy management strategy study on a fleet of connected and automated vehicles. In their research, a machine learning-based novel model predictive control energy management strategy is proposed to improve energy efficiency and ensure a safe spacing between adjacent vehicles. To be specific, a Gaussian process regression model is applied to predict the behaviors of human-driven vehicles given the distance between two vehicles and leading vehicle speed as the inputs. The novel method is evaluated in simulation in terms of energy saving and maximum spacing between adjacent vehicles.

Besides energy management, the battery system draws a significant amount of attention in the electrified vehicle community. This special issue has four articles related to battery systems. The fourth and fifth articles address battery thermal management, and the sixth and seventh articles address the battery state-of-charge and state-of-health estimation. In the fourth article, Siqi Chen et al. propose artificial neural network-based regression models in battery hybrid cooling system design, where the liquid coolant is mixed with a type of phase change material. The two individual neural networks are trained to predict the battery maximum temperature and temperature standard deviation of the hybrid cooling system, respectively. High training accuracies are achieved by the two networks, and experimental data are used in model validation. In the fifth article, Tim Gilles et al. applied the Markov decision process to generate representative driving cycles given the real customer operation scenario as the inputs for a plug-in hybrid fuel cell vehicle. These generated driving cycles also consider road gradient, which is important for the thermal load of the energy systems. The main advantage of the proposed cooling system design method is that it is customer-oriented and close to actual driving conditions.

For the state-of-charge and state-of-health estimation, in the sixth article, Stefano Feraco et al. applied artificial neural networks in battery state-of-charge estimation for a full hybrid electric vehicle. A nonlinear auto-regressive with exogenous input recurrent artificial neural network is utilized for its reported reasonable computation cost in prior research. The training data were experimentally collected in two battery packs of different sizes. Estimation accuracy and robustness are evaluated. In the seventh article, Luning Zhang et al. propose a novel impedance model parameter identification method based on a random mutation differential evolution algorithm. Compared with the chaos particle swarm optimization algorithm and genetic algorithm, the proposed algorithm shows fast convergence, high fitting accuracy, and high consistency. It is expected to complete the electrochemical impedance spectroscopy fitting in a powerful local computing unit or cloud server, thereby facilitating the battery state-of-health diagnosis.

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