SCIENCE CHINA
Information Sciences

• EDITORIAL •

July 2018, Vol. 61 070200
https://doi.org/10.1007/s11432-018-9393-2

Special focus on learning and real-time optimization of automotive powertrain systems*

The control of automotive powertrain systems is challenging for dynamical systems theory and control technology because of the complexity, uncertainty, and stochasticity in the dynamics. For mass production of a specified powertrain, normally over millions, a robust calibration of the electrical control unit (ECU) is the first requirement. However, since the operating environment always changes rapidly and the lifetime of a vehicle is longer, the pre-calibrated ECU parameter cannot guarantee the optimality of individual powertrain production systems; therefore, on-board learning and real-time optimization are required to improve efficiency. Moreover, the computing load for conducting on-board learning and optimization is no longer a bottleneck because of the rapid progress in ECU technology. This special focus comprises a review, five research papers, and three highlights to provide a leadership discussion forum for learning and optimization in automotive powertrain systems.

In automotive powertrain systems, combustion engine is a conventional power device; however, most controlled plants are challenging because of the uncertainty in the thermal dynamics and stochasticity in the in-cylinder combustion events. The review provides a brief summary of learning and on-line optimization technology for combustion control of engines, culled from recent research results of the author's group. The learning methodologies with keywords, extremal seeking, statistical learning, likelihood estimation, stochastic gradient descent algorithm, etc. are exploited to achieve optimal performance of power generation from the targeted combustion engines. The demonstrated experiments would be found interesting by automotive engineers and system control theorists. The first paper by Höckerdal E et al. discusses differential-algebraic equation-based extended Kalman filter (EKF) algorithm for diesel engines. Gong X et al. present a case study for controlling a novel free-piston engine generator, which provides new opportunity for improving efficiency of automotive powertrain with hybrid electric vehicles. Albin T discusses model predictive control issues for gasoline engines. Meanwhile, map-based control is the most typical ECU algorithm in automotive production. Nishio Y et al. present optimization problem for ECU map calibration. The detailed experimental results conducted at production level provide a practical case study. Weiss Y et al. propose a new yaw stabilizing control scheme for electric vehicles. Finally, the three highlights address stochastic logical control, battery model, and safety predictive control issues for electric vehicles.

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* **Citation** Shen T L, Eriksson L. Special focus on learning and real-time optimization of automotive powertrain systems. Sci China Inf Sci, 2018, 61(7): 070200, https://doi.org/10.1007/s11432-018-9393-2