Reinforcement Learning-Enabled Intelligent Energy Management for Hybrid Electric Vehicles

Synthesis Lectures on Advances in Automotive Technology

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The automotive industry has entered a transformational period that will see an unprecedented evolution in the technological capabilities of vehicles. Significant advances in new manufacturing techniques, low-cost sensors, high processing power, and ubiquitous real-time access to information mean that vehicles are rapidly changing and growing in complexity. These new technologies—including the inevitable evolution toward autonomous vehicles—will ultimately deliver substantial benefits to drivers, passengers, and the environment. Synthesis Lectures on Advances in Automotive Technology Series is intended to introduce such new transformational technologies in the automotive industry to its readers.

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Teng Liu
University of Waterloo

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ABSTRACT

Powertrain electrification, fuel decarburization, and energy diversification are techniques that are spreading all over the world, leading to cleaner and more efficient vehicles. Hybrid electric vehicles (HEVs) are considered a promising technology today to address growing air pollution and energy deprivation. To realize these gains and still maintain good performance, it is critical for HEVs to have sophisticated energy management systems. Supervised by such a system, HEVs could operate in different modes, such as full electric mode and power split mode. Hence, researching and constructing advanced energy management strategies (EMSs) is important for HEVs performance. There are a few books about rule- and optimization-based approaches for formulating energy management systems. Most of them concern traditional techniques and their efforts focus on searching for optimal control policies offline. There is still much room to introduce learning-enabled energy management systems founded in artificial intelligence and their real-time evaluation and application.

In this book, a series hybrid electric vehicle was considered as the powertrain model, to describe and analyze a reinforcement learning (RL)-enabled intelligent energy management system. The proposed system can not only integrate predictive road information but also achieve online learning and updating. Detailed powertrain modeling, predictive algorithms, and online updating technology are involved, and evaluation and verification of the presented energy management system is conducted and executed.

KEYWORDS

energy management, hybrid electric vehicles, reinforcement learning, deep learning, intelligent transportation information, real-time updating, velocity and power prediction, optimality and adaptability

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Preface

Electrified powertrains are encouraged as potential solutions to environmental concerns, desire for mobility, and safety concerns. Hybrid vehicles have been on the scene since the successful development of Prius by Toyota and Insight by Honda. Energy management strategies play a significant role in hybrid electric vehicles to achieve the goal of fuel economy improvement and pollution emissions reduction. Thanks to the existence of the internal combustion engine, battery pack, generator, and electric motor, the hybrid powertrain can work in pure electric and hybrid electric mode to accommodate driving conditions.

This book focuses on developing reinforcement learning-enabled energy management strategies for different hybrid powertrains. To the best of my knowledge, there has not been a book that systematically discusses the energy management strategies founded in artificial intelligence. Hence, this book aims to introduce the fundamental elements of reinforcement learning and various applications of reinforcement learning algorithms in the energy management field. The material assembled in this book is an outgrowth of the experience that the author gained while studying as a Ph.D. student in Beijing Institute of Technology, China, and working as a Postdoctoral Fellow of University of Waterloo, Canada.

The text mainly discusses the applications of reinforcement learning in energy management fields, including the optimality of signal algorithm and the mixture of multiple techniques. To apply the proposed system, methods, and framework into real-time applications of hybrid electric vehicles is the author's constant objective. I hope this book will interest graduate students, practitioners, and vehicle engineers in the area of hybrid electric vehicles.

Finally, I would like to express my heartfelt gratitude for the guidance and help of my family, supervisor, and colleagues. I am also grateful to all the editors for their support and patience in the production of this book. This book is also for my younger daughter, who was born on June 25, 2019.

Teng Liu
July 2019