Smart Mobility Solutions for Energy-Efficient Electrified Transportation: Eco-Driving Control Strategies

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The ongoing collaborative effort against climate change necessitates innovative solutions within the transportation sector, where the integration of advanced technologies holds promise in reshaping the environmental landscape. Within the array of solutions aimed at mitigating the carbon footprint of the transportation sector, the combination of powertrain electrification and advanced optimal controller emerges as particularly promising avenue.

This thesis delves into the development and evaluation of eco-driving controller solutions tailored for plug-in hybrid electric vehicles and fuel cell electric trucks. Through a comprehensive analysis, two distinct eco-driving strategies are proposed and tested, showcasing their potential to significantly reduce carbon emissions across light and heavy-duty transportation sectors. The first phase of the study builds upon preliminary research that was conducted for the US Department of Energy funded project called NEXT-Generation Energy Technologies for Connected and Automated On-Road Vehicles (NEXTCAR). The work herein presented focuses on designing a computational efficient energy management strategy for a complex hybrid electric vehicle to then implement it on an eco-driving controller based on Dynamic Programming, demonstrating adaptability across varying initial conditions and operational scenarios. Subsequently, an optimal control scenario is formulated for a fuel cell electric truck, involving the implementation of a complex control architecture based on Approximate Dynamic Programming. The significance of road altitude data in optimizing energy consumption is studied through a comparative analysis with a heuristic baseline strategy. The presented optimal controller demonstrated significant enhancements in hydrogen consumption, the magnitude of which was dependent upon driver aggressiveness and the availability of road altitude data. When compared to the baseline strategy, the ADP-based controller achieved hydrogen consumption improvements in the range 13% to 15% if road altitude is fully available. The study continues with a performance analysis of the proposed optimization algorithm when road

variability is introduced, particularly focusing on the effect of traffic queues. Through simulation studies and comparative analyses, the efficacy of the eco-driving controller was validated against the global optimal solution with the aid of a statistical tool, the probability density function. The outcomes demonstrated that the eco-driving controller offered close-to-optimal solutions in terms of energy consumption and travel time. Finally, the real-time applicability of the Approximate Dynamic Programming-based controller was analyzed, posing the foundations of future hardware-in-the-loop simulations.