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CONNECTED AUTOMATED VEHICLES AND ITS, ELECTRIC, FUEL CELL, AND HYBRID VEHICLE, VEHICLE DYNAMICS AND CONTROL

Eco-driving Profile Optimization by Dynamic Programming for Battery Electric Vehicles

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Abstract

Although full automation has not yet been achieved, automated vehicles are a valid research area. Not only would automated vehicles provide ultimate driver convenience, but they would maximize energy efficiency by eliminating undesired human driving behaviors and optimally controlling the powertrain. From the perspective of control related to energy saving, speed profile optimization is important for improving system efficiency and satisfying passenger demands. This study employs Dynamic Programming (DP) to solve the constrained optimal problem for travel time, distance, and speed limit by exploring all possible control options. The solutions obtained by DP demonstrate consistent control patterns combining four control modes—acceleration, cruising, coasting, and braking, with cruising or coasting being selective depending on the boundary conditions. This study introduces DP-based simulation results and attempts to provide comprehensive interpretations of the optimal policy by analyzing the essential factors that affect the control problem, including boundary conditions, road load, and powertrain characteristics. Based on these interpretations, the control concepts can be explained as the optimal policy selecting the best control option based on system efficiency and boundary conditions. The results of DP are compared with a human-like driver model to show that the optimal speed profiles can effectively reduce energy consumption.

Keywords Autonomous vehicles · Electric vehicles · Dynamic programming · Optimal control · Speed control

List of Symbols

s	Distance of vehicle, m
v	Vehicle speed, m/s
a	Vehicle acceleration, m/s^2
t_0	Departure time, s
t_f	Arrival time, s
s_f	Departure position, m
s_f	Arrival position, m
v_f	Departure speed, m/s
v_f	Arrival speed, m/s
a_{min}	Minimum acceleration, m/s^2
a_{max}	Maximum acceleration, m/s^2
F_d	Driving force, N
T_m	Motor torque, Nm
ω_m	Rotation speed of motor, rad/s
η_m	Efficiency of motor
η_c	Constant efficiency of motor
η_{drv}	Efficiency of drivetrain
r_{drv}	Total reduction ratio of drivetrain
R_{whl}	Wheel radius, m
m_{veh}	Vehicle mass, kg
F_r	Resistance force, N
c_0	Constant coefficient of coastdown, N
c_1	Linear coefficient of coastdown, N/(m/s)
c_2	Quadratic coefficient of coastdown, N/(m/s)^2
g	Gravitational acceleration, m/s^2
θ_l	Road slope, radian
P_e	Electrical power of motor, W
P_m	Mechanical power of motor, W
E_e	Electrical energy of battery, J
Δt	Discretized time step, s
a_d	Maximum comfortable acceleration, m/s^2
b_d	Comfortable deceleration, m/s^2

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