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MODEL PREDICTIVE ADAPTIVE CRUISE CONTROL OF INTELLIGENT ELECTRIC VEHICLES BASED ON DEEP REINFORCEMENT LEARNING ALGORITHM FWOR DRIVER CHARACTERISTICS

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ABSTRACT–This paper presents a novel model predictive adaptive cruise control strategy of intelligent electric vehicles based on deep reinforcement learning algorithm for driver characteristics. Firstly, the influence mechanism of factors such as inter-vehicle distance, relative speed and time headway (THW) on the driver's behavior in the process of car following is analyzed by the correlation coefficient method. Then, the driver behavior in the process of car following is learned from the natural driving data, the car following model is established by the deep deterministic policy gradient (DDPG) algorithm, and the output acceleration of the DDPG model is used as the reference trajectory of the ego vehicle's acceleration. Next, in order to reflect the driver behavior and achieve multi performance objective optimization of adaptive cruise control of intelligent electric vehicles, the model predictive controller (MPC) is designed and used for tracking the desired acceleration produced by the car following DDPG model. Finally, the performance of the proposed adaptive cruise control strategy is evaluated by the experimental tests, and the results demonstrate the effectiveness of proposed control strategy.

KEY WORDS : Intelligent electric vehicles, Adaptive cruise control, Deep reinforcement learning algorithm, Naturalistic driving data, Driver model

1. INTRODUCTION

In order to alleviate the drivers' burden and reduce the occurrence of traffic accidents, it is necessary to comprehensively coordinate the relationship among drivers, vehicles and traffic environment (Guo *et al*., 2019). To achieve this goal, Advanced Driving Assistance Systems (ADAS) have been developed, which employ the on-board sensor system to sense the environment and provide operational assistance for the drivers.

As one of the common systems of ADAS, Adaptive Cruise Control (ACC) system can keep the gap between the ego vehicle and the target vehicle ahead within a desired safe distance, so that the purpose of effectively reducing the driver's driving burden can be achieved. Vajedi and Azad (2015) presented an ecological adaptive cruise controller (Eco-ACC) for improving both fuel economy and safety of the Toyota Prius Plug-in Hybrid. Kim and Jerath (2021) designed a congestion aware Cooperative Adaptive Cruise Control (CACC) strategy as an alternative to address the trade-off between competing goals of raising the critical density, and reducing susceptibility to congestion observed at higher penetration rates of ACC-equipped vehicles. Haroon *et al*. (2019) presented a novel coordinated switching controller for the fuzzy PID ACC system that enhances the fuel efficiency, the proposed control strategies are compared for various traffic scenarios.

However, the current commercial ACC control system has some problems such as poor comfort and low acceptance. The driver's feeling is affected by many factors in the automatic car-following scenario (Mohtavipour *et al*., 2019; Wang and Horn, 2019; An *et al*., 2020). Therefore, the development of a longitudinal ACC control strategy that can more truly reflect the behavior characteristics of drivers in the process of car following is beneficial to improve the acceptance of the function of the car-following control system by the drivers. In order to be acceptable to drivers, the ACC systems need to be designed based on the analysis of human driver driving behavior (Moon and Yi, 2008). Wang *et al*. (2012) developed a prototype of a longitudinal driving-assistance system to be adaptive to the driver behavior, and its functions include adaptive cruise control and forward collision warning/avoidance. Su *et al*. (2018) presented a method to recognize drivers' behavior and intention based on the Gaussian Mixture Model, by means of a fuzzy PID control method, a personalized ACC control strategy was designed for different kinds of drivers to

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