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FUEL-SAVING CONTROL STRATEGY FOR FUEL VEHICLES WITH DEEP REINFORCEMENT LEARNING AND COMPUTER VISION

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ABSTRACT–This study uses deep reinforcement learning (DRL) combined with computer vision technology to investigate vehicle fuel economy. In a driving cycle with car-following and traffic light scenarios, the vehicle fuel-saving control strategy based on DRL can realize the cooperative control of the engine and continuously variable transmission. The visual processing method of the convolutional neural network is used to extract available visual information from an on-board camera, and other types of information are obtained through the vehicle's inherent sensor. The various detected types of information are further used as the state of DRL, and the fuel-saving control strategy is built. A Carla–Simulink co-simulation model is established to evaluate the proposed strategy. An urban road driving cycle and highway road driving cycle model with visual information is built in Carla, and the vehicle power system is constructed in Simulink. Results show that the fuel-saving control strategy based on DRL and computer vision achieves improved fuel economy. In addition, in the Carla–Simulink co-simulation model, the fuel-saving control strategy based on DRL and computer vision consumes an average time of 17.55 ms to output control actions, indicating its potential for use in real-time applications.

KEY WORDS : Deep reinforcement learning (DRL), Computer vision, Continuously variable transmission (CVT), Fuel economy

1. INTRODUCTION

In the past decades, with the vigorous development of the economy and the improvement of people's living standards, people's requirements for daily travel have greatly increased, and this increase has promoted the rapid development of the automobile industry. At the same time, ecological environment deterioration, fossil fuel shortage, and other adverse effects have emerged. Therefore, the rapid development of the automobile industry is the primary cause of environmental pollution and energy shortage (Zhang *et al.*, 2016; Yang *et al.*, 2020). With environment and energy issues in high priority, regulators in developed countries led by the U.S. and the European Union are setting increasingly strict emission standards to push automakers to upgrade existing technologies and produce highly fuel-efficient vehicles (Lutsey, 2012).

The world has put forward strict requirements on the energy saving performance and emission reduction of automobiles. Therefore, the introduction of highly advanced technology has become an urgent problem for automobile manufacturers. The current electric vehicle technology is imperfect, so the internal combustion engine will still have a large market share in the future (Li *et al.*, 2019). Given its unique transmission structure, continuously variable transmission (CVT) can continuously change the transmission ratio. As a result, CVT can ensure that the engine works in the optimal operating area, which greatly reduces fuel consumption and pollution emissions (Van der Meulen *et al.*, 2012). In this context, vehicles equipped with CVT have obvious advantages in energy conservation and emission reduction due to their highly flexible speed regulation performance.

Tang *et al.* (2018) analyzed the relationship between the engine, CVT state, and fuel consumption under different vehicle conditions, such as acceleration, constant speed, and deceleration, and proposed fuel-saving optimization strategies for vehicles equipped with CVT. Han *et al.* (2019) optimized the acceleration and coasting cycles of vehicles to reduce fuel consumption through optimal control theory. Lee *et al.* (2018) integrated the control of engine torque and CVT transmission ratio to determine the engine target torque and target transmission ratio by calculating the engine operating point that minimizes instantaneous fuel consumption. However, these studies have focused on optimizing engine and transmission efficiency and ignored the influence of external information on vehicle fuel consumption, resulting in poor optimization results. To achieve ideal optimization results, the optimal efficiency of the engine and transmission and the prediction information about the behavior of other vehicles or the

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