Abstract

With the rapid development of autonomous vehicle technology in recent years, automated vehicles (AVs) may become the main means of transportation in the future. Before the era of autonomous driving truly arrives, the next 10 to 50 years will still be a transitional period in which human-driven vehicle (HVs) and automated vehicles coexist. Therefore, this paper aims to research on the driving strategy of AVs in mixed traffic and explore the optimal penetration rate of AVs, so that AVs could shuttle through the road at its optimal speed, and better improve the capacity of road traffic system.

First, under the MDP (Markov Decision Process) framework, applied reinforcement learning technology to AVs, training them to self-learn driving strategies based on historical experience. The training process of AVs was carried out under the table-format-based Q-learning method. Specifically, AVs adopted the ε-greedy search strategy to select the immediate action, enabling it move in the direction of "self-interest" (that is, to drive in the direction with the highest possible speed providing stable and safe condition). In this learning mode, AVs not only considered immediate rewards but also counted the future benefit into the scope of trade-offs and estimates, making the automated vehicle own a "long-term" vision. After the training, AVs had both "foreseeing" ability and "seeing stitching" ability in order to make better use of road resources and improve its operating efficiency.

Through microscopic traffic simulation, the effectiveness of the self-interest strategy of automated vehicles in free-flow, critical density, and low-congestion scenarios was verified, and the driving strategy of autonomous vehicles in different scenarios was obtained. At the same time, the following conclusions are drawn regarding the impact of AVs and HVs on mixed flow: 1) The increase in the proportion of automated vehicles within a certain range can improve the efficiency and stability of mixed traffic flow. The traffic capacity of pure automated vehicle traffic is increased by 33.55% compared to pure human-driven traffic; 2) 70% can be used as the reference ratio of the best automated vehicle penetration rate; 3) Under the high automated vehicle penetration rate (90% ~ 100%), only a small number of human-driven vehicles have a greater impact on the flow of the mixed traffic, the average driving time, and the degree of congestion . The impact of 0.33% human-driven vehicles on the overall flow of the system is about 13 times its own proportion.

To reduce the training times, we also explored the applicability of the self-interest strategy of AVs in different traffic scenarios. The results show that the training result of intermediate density scenario is fully applicable to other densities at low AV penetration rates; and are much applicable to other densities at lower-middle AV penetration rates. Moreover, the training result of the intermediate AV penetration rate scenario is only applicable to the lower AV penetration rates; when applied to the high AV penetration rates, there is a large error, especially when applied to pure AV traffic flow, the error reaches maximum.

On the one hand, this paper proposed automated vehicle driving strategies based on reinforcement learning, which better meets the uncertainty and intelligence characteristics of autonomous driving; On the other hand, investigating the effect of automated vehicles on mixed traffic flow lays the foundation for controlling the number of automated vehicles on the road in the future, increasing the speed of AVs and improving the efficiency of traffic system.

Keywords: automated vehicles, self-interest strategy, reinforcement learning, man-machine mixed traffic