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Smooth longitudinal driving strategy with adjustable nonlinear reference model for autonomous vehicles

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Abstract

Comfort in Autonomous Vehicles (AVs) is a decisive aspect and plays an essential role in their advanced driving systems. As the comfort is directly influenced by the amount of acceleration and deceleration, a smooth longitudinal driving strategy can significantly improve the passenger's acceptance level. Although some safe longitudinal strategies such as time-headway are introduced for AVs, the breakpoints in their speed generation models when approaching the front vehicle made discomfort behavior. In this paper, we proposed a continuous and differentiable reference speed model with a single equation to cover all possible relative distances. This model is constructed based on the well-known attributes of a hyperbolic tangent curve to smoothly change the speed of the host vehicle at the corner points. Moreover, the adjustable variables in our reference speed generator make it possible to choose between low and high-accelerate driving strategies. The experiments are performed based on several driving scenarios such as stop-and-go, hard-stop, and normal driving, and the results are compared with different reference speed models. The maximum improvement is obtained in the stop-and-go scenario, and on average, about 7.29 and 12.47% are achieved in terms of the magnitude of acceleration and jerk, respectively.

Keywords Unmanned Vehicles · Advanced driver-assistance systems · Smoothness control · Passenger comfort

1 Introduction

Recent advancements in automobile and electronic technologies have shown promising solutions and practical developments for future AVs. In each AV, several intelligent systems including sensors, hardware, and software are required to automatically control and navigate the vehicle satisfying the passenger's requirements. Some of them are Adaptive Cruise Control (ACC) [1], Collision Avoidance Systems (CAS) [2], Steering Control Systems (SCS) [3], and Lane Change Assist Systems (LCAS) [4]. The impact of these systems on the quality of driving is so deniable that most vehicle manufacturers try to install them in recent models of products. It was reported that smart control of vehicles on highways not only improves the traffic jams situations but also reduces the number of accidents caused by human errors and distractions [5]. To build such systems, it is recommended to exploit high-level sensing devices like navigation, radar and laser data reception, visualization, and vehicle-to-vehicle data transmission. Moreover, recent machine vision techniques based on deep convolutional neural networks simplified complex computations in AVs systems, such as object detection for environment and road monitor. After receiving data from these devices, intelligent control methods will be applied to produce desirable signals for actuations. AVs have many control methods based on different approaches like fuzzy logic or neural network to maintain the control error between the measurements and desirables as low as possible. To reach low-error control rates in AVs, both the safety and comfort of passengers must be taken into account simultaneously. Actuations parts are mainly categorized into throttle,

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