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IMPROVED RESPONSIBILITY-SENSITIVE SAFETY ALGORITHM THROUGH A PARTIALLY OBSERVABLE MARKOV DECISION PROCESS FRAMEWORK FOR AUTOMATED DRIVING BEHAVIOR AT NON-SIGNALIZED INTERSECTION

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ABSTRACT–Self-driving safety is one of the major concerns raised with regard to pushing the use of automated vehicles on roads. Fully automated vehicles are forced to make appropriate decisions in an uncertain environment where driverless and human-driven vehicles share the road together. This study proposes a new model that can be used to enhance the autonomous driving behavior at a non-signalized intersection considering the traffic safety guarantee, delay time, and smooth driving. The proposed model is called the responsibility-sensitive safety-based partially observable Markov decision process model for the decision-making mechanism of automated vehicles. The model not only increases traffic safety guarantee and smooth driving, but also reduces the delay time. First, we generate some specific driving scenarios using the automated driving toolbox in MATLAB. Second, the driving strategy of automated vehicles is optimized by the partially observable Markov decision process framework using the adaptive cruise control system. Finally, the responsibility-sensitive safety algorithm is implemented under adaptive model predictive control. The proposed model performs better than the classical adaptive model predictive control. In the best case, the proposed model took a 31.60 % reduction in braking time and a 51.20 % improvement in smoothing speed control.

KEY WORDS : Autonomous decision making, Responsibility-sensitive safety, Partially observable Markov decision process, Adaptive cruise control, Self-driving safety

1. INTRODUCTION

Safe driving is one of the main challenges not only for traffic management agencies, but also for traffic participants. Based on a national motor vehicle crash survey, 47 % of collisions in 2015 usually happened at intersections (National Highway Traffic Safety Administration, 2016). Automated vehicles (AVs) have recently shown the potential to prevent human errors and improve the quality of traffic service. This means of transportation can save approximately $450 billion for the economy of the United States each year (Fagnant and Kockelman, 2015). An Automated vehicle (AV) testing has increasingly spread among manufacturers, including Waymo, GM, BMW, Ford, Volkswagen, and Volvo. Accordingly, planning systems, including mission, behavior, and motion planning, of the Defense Advanced Research Projects Agency have been adopted by the testing system (Urmson *et al*., 2008). An automated robot testing has also proven abilities for navigating in other robots and manually driven vehicles (Montemerlo *et al*., 2008). More importantly, advance in the self-driving technology is considered as an ideal solution to enhancing the traffic safety and monitoring the driving behavior. However, one barrier for this advancement is the legislation related to the certification of safety. The real situations and solutions for the regulations of automated vehicles have been presented in Brodsky (2016). Moreover, the necessity of safety certification and the challenge of fully self-driving vehicles have been discussed with regard to safety, interaction between machine and human, social approval, and certification (Koopman and Wagner, 2017). However, a single vehicle could not ensure complete guarantee safety based on its behavior. Instead, Shalev-Shwartz *et al.* proposed a mathematical model, which could formalize human judgment for autonomous decision making related to all driving situations. This approach was called responsibility-sensitive safety (RSS) (Shalev-Shwartz *et al*., 2017). According to Shalev-Shwartz, Mobileye released the RSS design in its autonomous program (Mobileye, 2017). The RSS algorithm must comply with rules, namely longitudinal distance, lateral distance, right of way, and safe driving with limited sensing. Therefore, it could be useful for the true safety agreement of automated vehicles.

AVs could also operate in an uncertain environment, such

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