Social-aware Planning and Control for Automated Vehicles based on Driving Risk Field and Model Predictive Contouring Control

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EXTENDED ABSTRACT

Purely fully autonomous vehicles on roads are demonstrated to be beneficial to road safety and efficiency. However, the gradual development and deployment of automated vehicles (AVs) and advanced driver assistance systems (ADAS) at various levels results in mixed traffic conditions where AVs need to interact with human-driven vehicles (HDVs). Thus, making AVs' behavior understandable, expected, and accepted by human drivers through so-called social-aware driving models is critical for road safety and efficiency under various maneuvers, especially challenging ones, e.g., driving on weaving sections, highly curved roads, and driving through roundabouts.

Previous research has mainly focused on the trajectory planning of AVs using Model Predictive Control or other relevant models, while seldom considering the integrated planning and control of AVs altogether. Moreover, there are very limited studies on social-aware driving and none when it comes to the challenging maneuver of driving through roundabouts. Several challenges are lying ahead. The first one is to ensure the safety and comfort of all users on the road. It is important to understand the intention of human drivers correctly and try to work with the HDVs correspondingly. Machines and humans do not understand the danger/risk in the same way. Thus, what AVs need is to "think" more like humans and anticipate possible dangers to interact with other HDVs safely. Furthermore, for social-aware driving, it is necessary to modify the AV's original objective by balancing its own benefits versus the benefits of other surrounding HDVs considering the different driving styles and characteristics of human drivers, thus making the AV accepted by HDVs. Different human drivers possess different priorities concerning safety, efficiency, and attitudes toward other vehicles, reflecting their different driving styles, e.g., aggressive, and defensive. Also, the driving style of AVs determined by the needs of the passengers may vary from time to time, and case by case. For example, for daily commuters and those in a hurry, the efficiency of their journey should be assigned with a higher priority. While, if there is an elderly or sick person in the vehicle, he/she probably will place more weight on comfort level and be more willing to give precedence to others to ensure safety. Finally, it is challenging for the model to maintain robustness in tackling different scenarios and handling different driving styles.

To fill the aforementioned research gaps and address the challenges, this paper develops an integrated social-aware planning and control algorithm, i.e., DRF-SVO-MPCC, which incorporates Driving Risk Field (DRF), Social Value Orientation (SVO), and Model Predictive Contouring Control (MPCC) to enable AVs to consider HDVs' risk and balance their own benefits with regards to the benefits of HDVs. The DRF is used to model the perceived risk and SVO is adopted to measure how AVs make the trade-off between their own benefits and the benefits of other HDVs. Using the SVO-based DRF and MPCC costs, together with the desired velocity, this study implements two types of driving styles, i.e., prosocial and egoistic. The model-based DRF-SVO is packaged into the cost function established by MPCC to deliver integrated planning and control. The proposed DRF-SVO-MPCC model is tested and verified on various simulation experiments comparing with two baselines which demonstrates its good planning and control performance driving through both single-lane and two-lane roundabouts with or without interacting with HDVs. Some demo videos of the testing are already available at: https://shorturl.at/lBHM9.