A Data-driven Simulation of Naturalistic Driving Environment for Autonomous Vehicle Testing

Xintao Yan\textsuperscript{a}, Shuo Feng\textsuperscript{a}, Haowei Sun\textsuperscript{a}, Henry X. Liu\textsuperscript{a,b}

\textsuperscript{a}Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI, USA
\textsuperscript{b}University of Michigan Transportation Research Institute, University of Michigan, Ann Arbor, MI, USA

Abstract

Microscopic traffic simulation provides a controllable, repeatable, and efficient testing environment for Autonomous Vehicles (AVs). To evaluate AVs’ safety performances in the real world, it is critical to test AVs in the simulation of the naturalistic driving environment (NDE). Although human driving behaviors have been extensively investigated in the transportation engineering domain, most existing models were developed for traffic flow analysis purposes. For AV testing purposes, however, the NDE needs to reproduce the critical environment measurements (e.g. speed and spacing) that are distributionally consistent with the real-world driving environment. Only with consistent distributions, simulation results can unbiasedly evaluate AVs’ safety performances. To generate such a simulation, we propose a data-driven NDE modeling method, including the initialization method and the vehicle behavioral modeling method. To guarantee the consistency, the NDE is modeled as a Markov chain, and its stationary distribution is twisted as the empirical distributions from the real-world naturalistic driving data (NDD), through optimizing the vehicle behavior models. We utilized the NDD from the Safety Pilot Model Deployment (SPMD) dataset at the University of Michigan, Ann Arbor. The performance of the proposed method is validated for the highway driving environment by both microscopic and macroscopic measurements. The microscopic measurements, i.e., speed and spacing distributions, generated by simulations are consistent with real-world distributions. In addition, the proposed NDE can also reproduce many complex phenomena of highway traffic flows, including shockwaves and fundamental diagram. These results indicate that constructed NDE can better imitate real-world driving situations for AV testing purposes than existing methods. To further validate the capability for AV testing, the generated NDE is utilized to test the safety performance of an AV model. The experiments show that the generated NDE can effectively evaluate AV safety performance and produce diverse accident cases that are valuable for AV development.

Keywords: Naturalistic driving environment, Driving behavior, Autonomous Vehicle, Testing and evaluation, Simulation