Project Title: Generating Safety-Critical Driving Scenarios for the Design of the CAV Proving-Ground - using domain knowledge, causality, and large language models.

Recipient/Grant (Contract) Number: Carnegie Mellon University, Grant #: 69A3552344811

Center Name: Safety21 National University Transportation Center for Promoting Safety

Research Priority: Promoting Safety

Principal Investigator(s): Ding Zhao Carnegie Mellon University

PI Contact: dingzhao@cmu.edu

Project Partners:

- Google
- PennSTART
- City of Pittsburgh

Research Project Funding: $100,000.00

Project Start and End Date: 07-01-2023 to 06-30-2024

Project Description:

Connected Autonomous Vehicles (CAVs) have witnessed significant advancements in recent years, largely due to the progress in machine learning-enabled sensing and decision-making algorithms. A paramount challenge for their widespread deployment in the real world, however, is safety evaluation. While most existing driving systems are trained and evaluated using naturalistic scenarios from daily life or heuristically generated adversarial ones, safety-critical scenarios are extremely rare considering the sheer number of cars on the road. This leads to very imbalanced data and high cost for data collection. Consequently, methods that can generate realistic risky scenarios become essential for safety assessment and cost reduction. This research aims to enhance the testing procedures for Connected and Autonomous Vehicles by generating critical driving scenarios. These scenarios play a pivotal role in ensuring the safety and reliability of CAVs before they are deployed on roads. We plan to incorporate domain-specific knowledge about driving and road conditions, draw on causality inferences to comprehend the sequences of events leading to critical situations, and utilize the reasoning abilities of large language models to produce realistic and diverse driving scenarios. By incorporating these components, we aim to develop a holistic testing framework that presents a more accurate depiction of real-world driving challenges for CAVs. This will not only boost the robustness of CAV testing but also guide the design of proving grounds. Specifically, we will collaborate with PennSTART to implement our scenario generation approach in designing a proving ground for CAVs in Pennsylvania. Additionally, we'll harness augmented reality technologies to amplify the capabilities of the physical infrastructure by integrating virtual road users, including wheelchair users and the visually impaired. Our ultimate objective is to make a tangible real-world impact, potentially through technology transfer or the launch of a startup.

Outputs:

A digital twin platform of connected autonomous vehicle testing ground based on an open-source platform. Algorithms for generating safety-critical scenarios in digital twins, including Domain Knowledge with Tree Structure Representation, Causal Autoregressive Flow for Scenario Generation, and Large Language Models for Scenario Generation. Several designs of proving grounds for PennSTART. Patent filings and potential tech transfer.

Outcomes/Impacts:

The primary anticipated outcome of this research is to establish a proof-of-concept for deploying

safety-critical scenario generation methods for CAV testing and proving-ground design. Through collaboration with the design of proving ground, the project holds the potential to formulate new transportation policies, regulations, and practices, thereby contributing to a safer, more reliable, and efficient autonomous driving environment. We will work closely with PennSTART to design the physical infrastructure for the CAV proving ground at Pennsylvania and also implement the scenarios with augmented reality.