CENTER FOR CONNECTED AND AUTOMATED TRANSPORTATION

UTC Project Information	
Project Title	CAV Testing Scenario Design and Implementation using Naturalistic Driving Data and Augmented Reality
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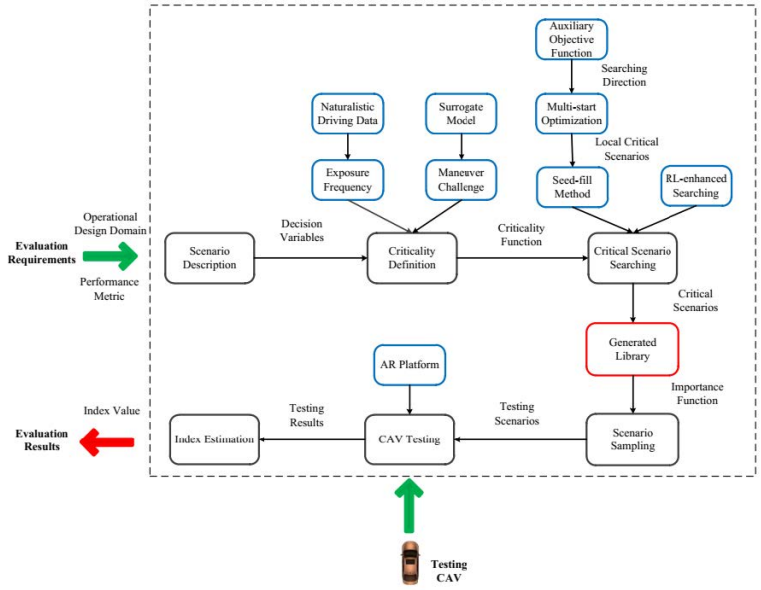
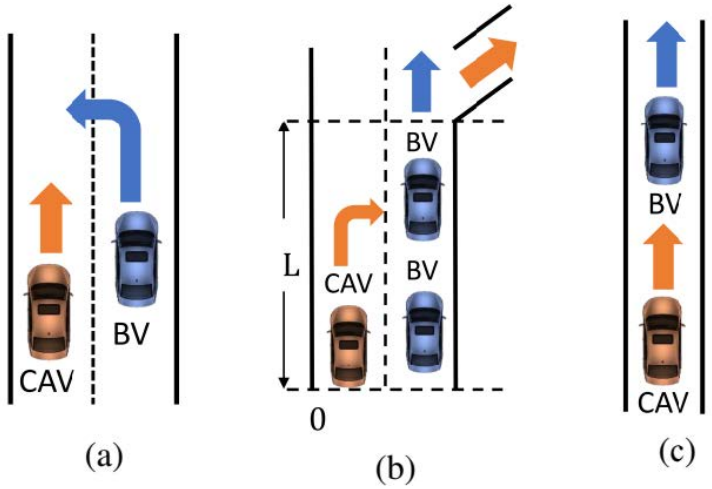
Funding Source(s) and Amounts Provided (by each agency or organization)	$131,025 (CCAT)
Total Project Cost	$131,025
Agency ID or Contract Number	69A3551747105
Start and End Dates	01/10/2017 – 06/30/2022
Brief Abstract of Research Project	Testing and evaluation is a critical step in development and deployment of connected and automated vehicle (CAV) technology. Testing standards for human driven vehicles, such as Federal Motor Vehicle Safety Standards (FMVSS), have been established a long time ago. However, current standards cannot be applied to CAVs, because they often assume the presence of a human driver, who conducts the driving tasks. It is very important to develop test procedures and identify applicable testing scenarios (user cases) for CAVS to evaluate the "intelligence" of the vehicle. The intelligence level indicates whether a CAV can drive safely and efficiently without human intervention. The newly released Automated Driving Systems Guideline 2 has made it very clear that the new automated driving systems needs validation methods and needs to be tested by incorporating behavior competencies. In this project, we will investigate how to design such testing scenario libraries by looking into crash and naturalistic driving databases, and how to implement the defined scenarios in the augmented reality

	(AR) testing environment. We focus on testing higher levels of automation defined by SAE (level 3 or higher), in which human behaviors are much less involved in the driving tasks. A general framework work will be proposed to generate testing scenarios and with theoretical foundations. Several representative testing scenarios will be identified and implemented in the augmented reality (AR) testing environment. The identified testing scenarios will first be constructed in the simulation platform with realistic driver behaviors calibrated from naturalistic driving data (NDD). A real CAV will be tested under the scenarios and its performance will be recorded and evaluated in terms of accuracy and efficiency.
Most Relevant CCAT Research Thrusts	__x__ Enabling Technology _____ Policy & Planning __x__ Human Factors _____ Infrastructure Design & Management __x__ Control & Operations __x__ Modeling & Implementation
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	Testing Scenario Library Generation (TSLG) Framework The general framework for the TSLG problem is illustrated in Figure 1, which includes scenario description, criticality definition, critical scenario searching, library generation, scenario sampling, and CAV testing and index estimation.  Figure 1: An illustration of the proposed framework to the TSLG problem Case Studies

	Three categories of scenarios are designed, as shown in Figure 2, to demonstrate the performance of the proposed framework (1) Cut-in case: a background vehicle (BV) makes a lane change in front of the testing CAV. (2) Highway exit case: the testing CAV needs to make a lane change to the right and exits the highway within a certain distance. (3) Car-following case: the testing CAV follows a BV for certain time.  Figure 2: An illustration of the three cases: (a) cut-in, (b) highway exit, and (c) car-following
Impacts/Benefits of Implementation (actual, not anticipated)	In this research, a unified framework is designed to solve the entire TSLG problem, where a novel method is proposed for the library generation question. Theoretical analysis provides justifications of the proposed method regarding for both evaluation accuracy and efficiency. Specifically, the proposed method obtains unbiased index estimation of performance metrics (i.e., accuracy) with fewer number of required tests (i.e., efficiency). The three case studies verify the proposed methodology and the results show that the evaluation process can be accelerated by 255 to 3.75×105 times compared with the NDD evaluation method, with the same accuracy.
Web Links • Reports • Project website	ccat.umtri.umich.edu