UNIVERSITY OF MICHIGAN Mcity

LEADING THE TRANSFORMATION
TO CONNECTED AND AUTOMATED VEHICLES

Safety Assessment for Highly Automated Vehicles

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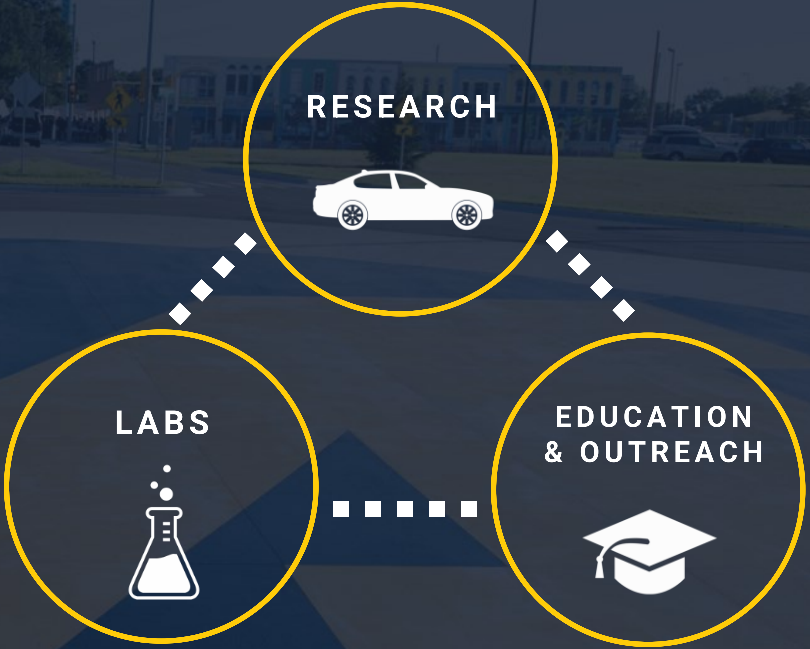
December 14, 2023

Mcity and Center for Connected Automated Transportation (CCAT)



Mcity test facility is the world's first purpose-built proving ground for connected and automated vehicles.

Mcity was built by a public-private partnership between UM, MDOT, and our industry partners. Mcity was open for operation in July 2015.

Agenda

1. Safety Challenges for Autonomous Vehicles (AVs)
2. Mcity Safety Assessment Program for AVs
    1. AV Driver Licensing Test
    2. AV Driving Intelligence Test
3. Mcity 2.0

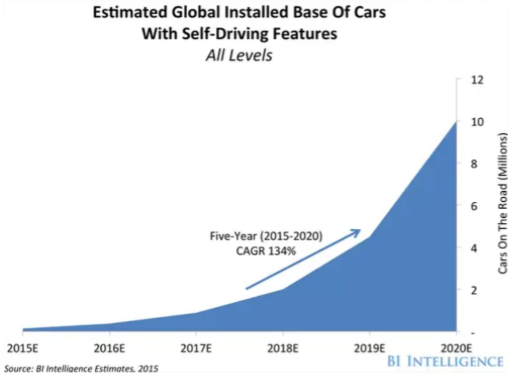
Automated Vehicle Technology Hypes in 2016

HOME > TECH

10 million self-driving cars will be on the road by 2020

Insider Intelligence , BI Intelligence Updated Jun 15, 2016, 7:25 AM

Self-driving cars are no longer a futuristic idea. Companies like Mercedes, BMW, and Tesla have already released, or are soon to release, self-driving features that give the car some ability to drive itself.



BI Intelligence

Automated Vehicle Technology Downfalls in 2022

FORTUNE RANKINGS MAGAZINE NEWSLETTERS PODCASTS MORE SEARCH SIGN IN Subscribe Now

A long, cold winter is here for self-driving cars

BY **ALEXEI ORESKOVIC**

October 18, 2022 at 3:11 PM CDT

Cruise suspends all driverless operations nationwide

Cruise, GM's robotaxi service, suspends all driverless operations nationwide

Associated Press

Published 12:46 p.m. ET Oct. 27, 2023 | **Updated 12:47 p.m. ET Oct. 27, 2023**

View Comments

NEW YORK — Cruise, the autonomous vehicle unit owned by General Motors, is suspending driverless operations nationwide days after regulators in California found that its driverless cars posed a danger to public safety.

The California Department of Motor Vehicles revoked the license for Cruise, which recently began transporting passengers throughout San Francisco, this week.

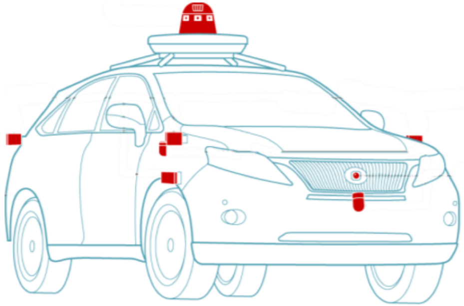
Cruise is also being investigated by U.S. regulators after receiving reports of potential risks to pedestrians and passengers.

Major gap exists in safety performance

Human Drivers

1 accident every ~10^6 miles

Automated Vehicles



1 disengagement every $\sim 10^4$ miles

2020 Disengagement Report from California DMV

Curse of Dimensionality (CoD)

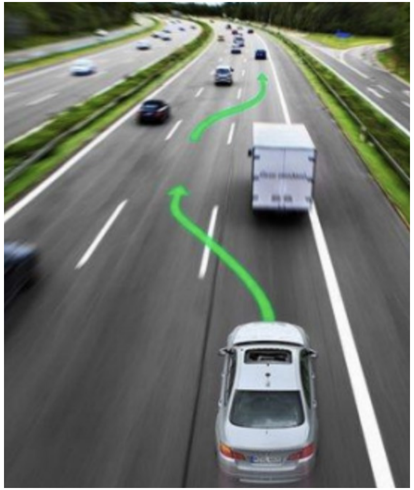
The CoD Problem is that when the dimensionality increases, the volume of the space increases so fast that the available data become sparse.

Weather

Road Infrastructure

Road Users

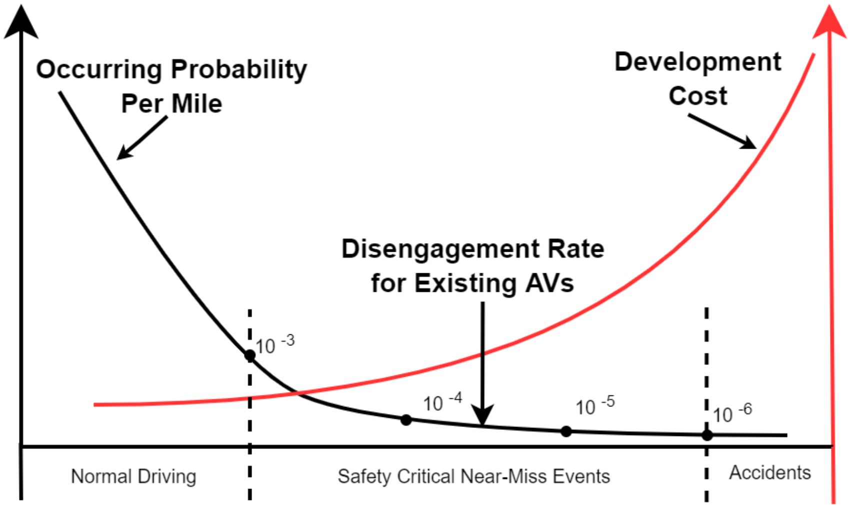
Maneuvers



Curse of Rarity (CoR)

- The basic concept of CoR is that the occurrence probability for the events of interest is so rare that most available data contain little information regarding the rare events.

- Similar challenges exist for other safety-critical autonomous systems such as medical AI, aerospace autonomous system, and battery management, etc.



Liu, H. and Feng, S. (2022) “Curse of Rarity” for Autonomous Vehicles, Preprint at https://arxiv.org/abs/2207.02749

Safety Challenges for AVs

For AVs, both CoR and CoD problems exist — the rarity of safety-critical events in high-dimensional driving environments — are the root causes of various safety challenges in the development and deployment of AVs.

The current deep learning algorithms cannot handle this type of cases.

AV Safety Validation Challenges

1.1 deaths per 100 million miles (According to NHSTA in 2019)

To prove AV's are 20% better than human drivers using a fleet of 100 AV's driving 25 mph:

Avoiding Crashes – 28M miles (1.3 years)

Avoiding Injuries –170M miles (7.6 years)

Avoiding fatalities – 5B miles (225 years)

Kalra, Nidhi and Susan M. Paddock, Next Stop, Neptune? Why We Can't Rely on Test-Driving Alone to Assess the Safety of Autonomous Vehicles, Santa Monica, Calif.: RAND Corporation, IG-128, 2017. As of April 08, 2021: https://www.rand.org/pubs/infographics/IG128.html

Existing testing methods

Simulation

Test Track

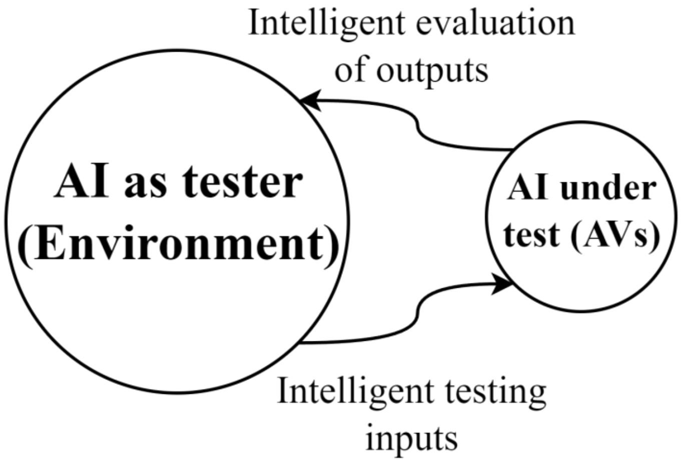
On-Road

Low Fidelity

Lack of Traffic

Time & Cost Expensive

Our approach: AI against AI



Intelligence is needed to test & evaluate another intelligence

Mcity Safety Assessment Program for Autonomous Vehicles

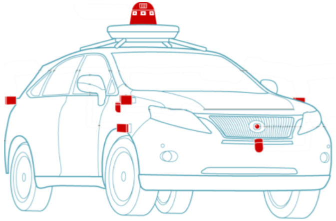
Part 1: Driver Licensing Test

- Basic behavior competency evaluation to ensure minimum performance levels
- Select scenarios and test case parameters based on ODD

Part 2: Driving Intelligence Test

- Comprehensive performance evaluation to specify occurrence rate of measurable safety behavior
- In comparison to a human reference driver in naturalistic driving environment

v.s.



\+ Automated Driving System

Driver Licensing Test

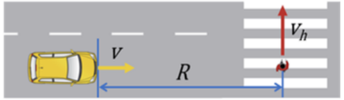
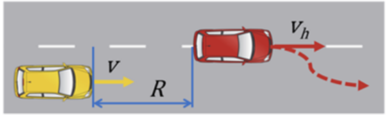
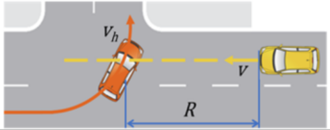
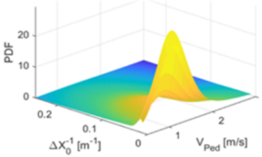
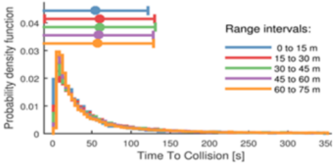
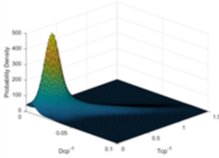
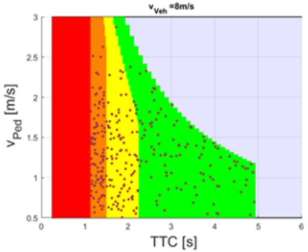
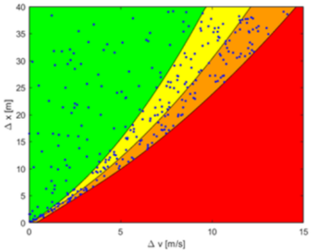
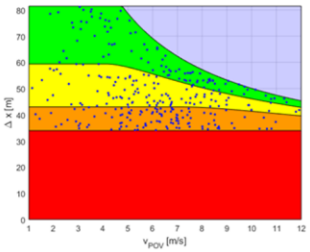
- Many million-miles through **Accelerated evaluation** for systematic thoroughness

- **Behavior competence**
  - Scenario Library
  - Select scenarios and test case parameters based on ODD

- **Corner cases**
  - Examine AV at the “safety boundary”

M | city

Driver Licensing Test (Cont'd)

	Pedestrian Crossing	Cut-in	Left turn
			
Naturalistic driving data	2,689 events (camera)	145,595 events (SPMD)	1,055 events (IVBSS)
Stochastic model			
Accelerated evaluation framework and simulation			

M city

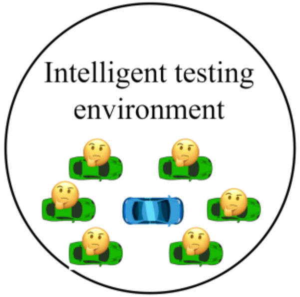
Driver Licensing Test

Cut-in

Left-turn

M city

Driving Intelligence Test



Naturalistic Driving Data (NDD)

→

Naturalistic Driving Environment (NDE)

→

Naturalistic and Adversarial Driving Environment (NADE)

To reproduce the real-world traffic environment

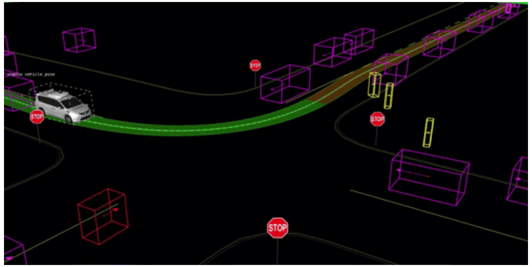
Unbiasedness

To accelerate the AV testing process

Efficiency

Limitations of existing NDE models

Replay Logged Data



Source: Waymo

- Non-reactive
- Not scalable and efficient

Heuristic Rules

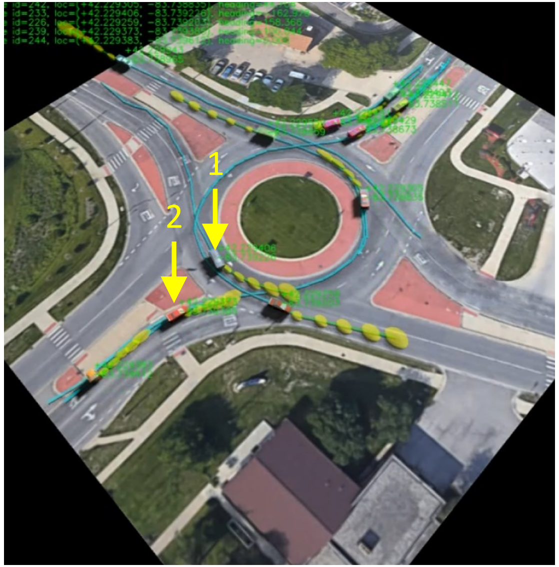
CARLA

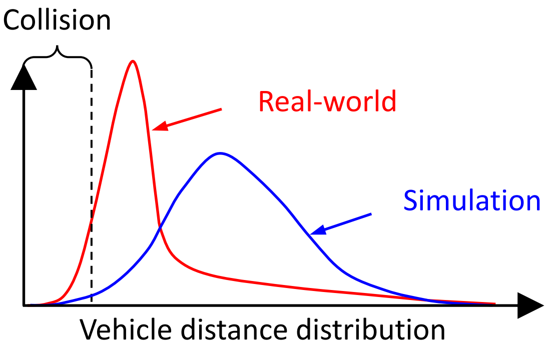
SUMO

- Oversimplified based on heuristic rules
- Hard to generalize and model complex scenarios and interactions

NDE simulators could be misleading!

Example of yielding at a roundabout





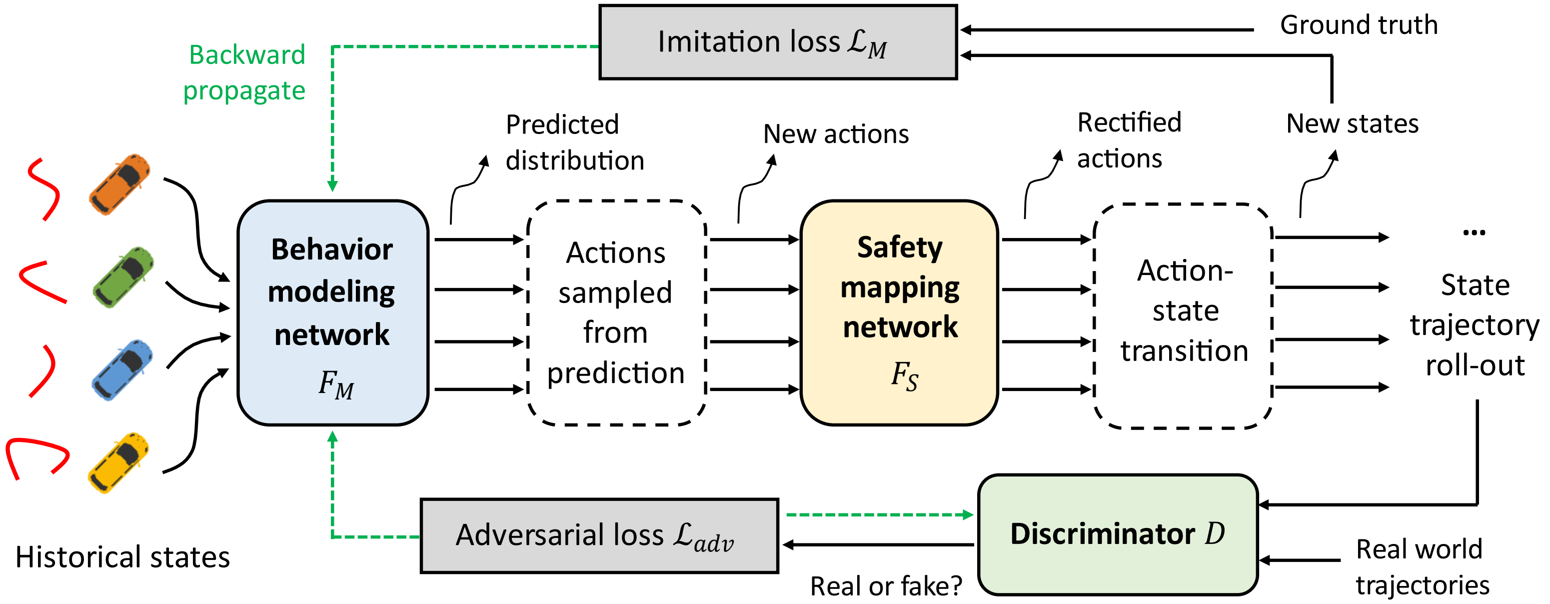
Statistical Unrealism → Could mislead the AV development

E.g., Underestimate the AV accident rate

E.g., Train aggressive AV yielding models

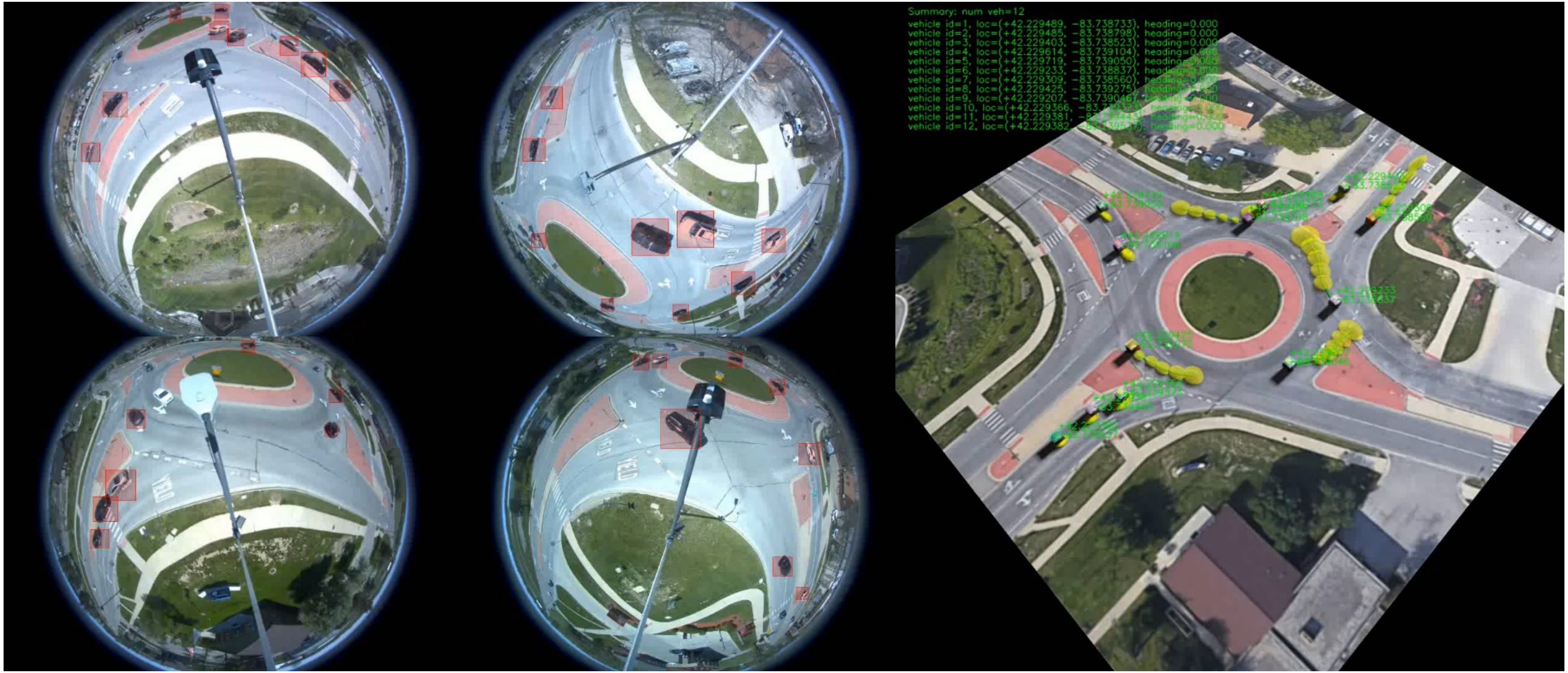
NeuralNDE: A deep learning based framework

- Model long-term multi-agent interaction behaviors in complex traffic environment without any heuristic rules.

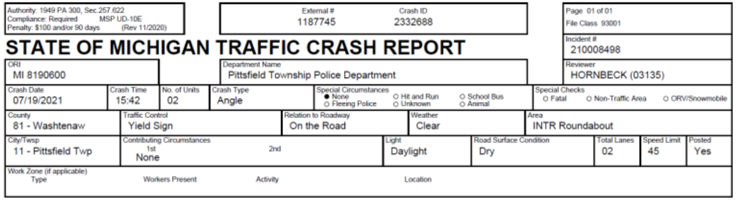


Yan et al., 2023, Learning naturalistic driving environment with statistical realism, *Nature Communications*, 14, 2037.

High-resolution trajectory data collection



Crash/Near-Miss Detection



Authority: 1949 PA 300, Sec.257.622
Compliance: Required MSP UD-10E
Penalty: $100 and/or 90 days (Rev 11/2020)

External # 1187745 Crash ID 2332688

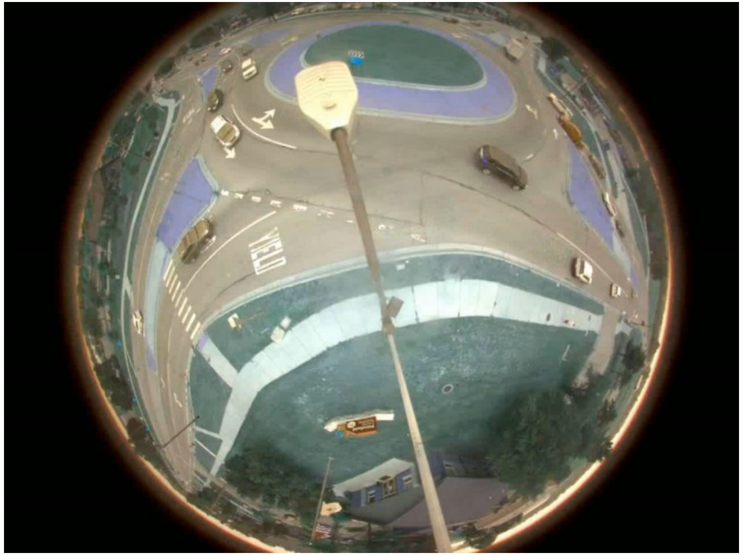
Page 01 of 01
File Class 93001

STATE OF MICHIGAN TRAFFIC CRASH REPORT

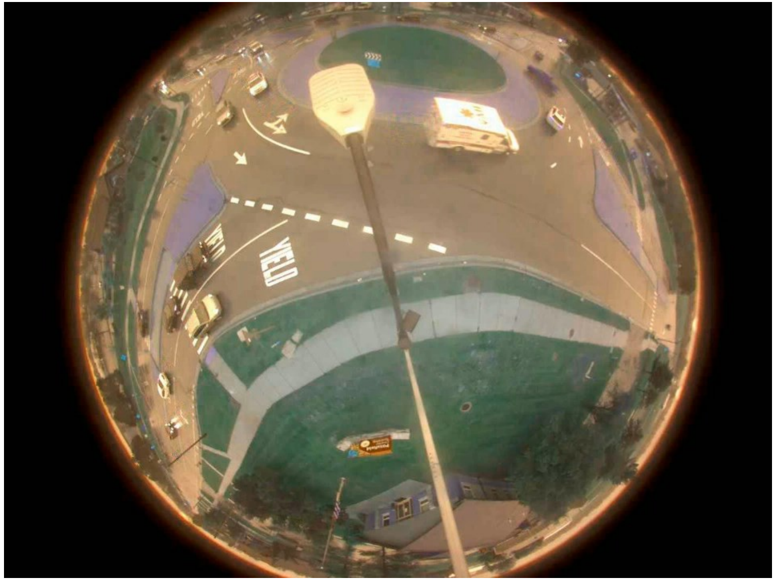
Incident # 210008498

ORI: MI 8190600	Department Name: Pittsfield Township Police Department				Reviewer: HORNBECK (03135)	
Crash Date: 07/19/2021	Crash Time: 15:42	No. of Units: 02	Crash Type: Angle	Special Circumstances: ● None ○ Fleeing Police ○ Hit and Run ○ Unknown ○ School Bus ○ Animal	Special Checks: ○ Fatal ○ Non-Traffic Area ○ ORV/Snowmobile	
County: 81 - Washtenaw	Traffic Control: Yield Sign	Relation to Roadway: On the Road	Weather: Clear	Area: INTR Roundabout		
City/Twsp: 11 - Pittsfield Twp	Contributing Circumstances: 1st None 2nd	Light: Daylight	Road Surface Condition: Dry	Total Lanes: 02	Speed Limit: 45	Posted: Yes
Work Zone (if applicable): Type	Workers Present	Activity	Location			

Crash verified with police report



Near-Miss Detection (More than 100 times of number of crashes)



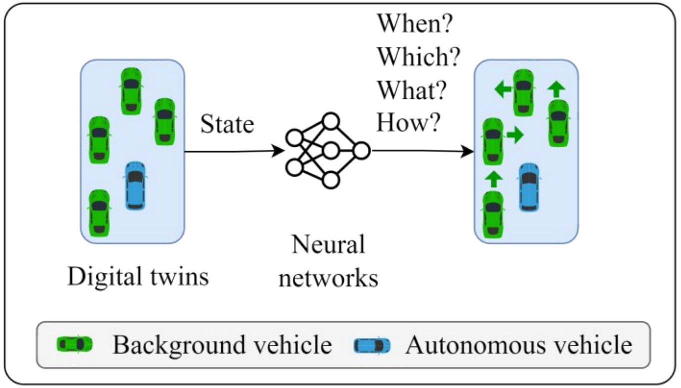
Naturalistic Driving Environment Simulation

Example 1:
Angle crash caused by failure to yield

Naturalistic and Adversarial Driving Environment (NADE)

Real world

+



Intelligent testing environment

Augmented world

We aim to know

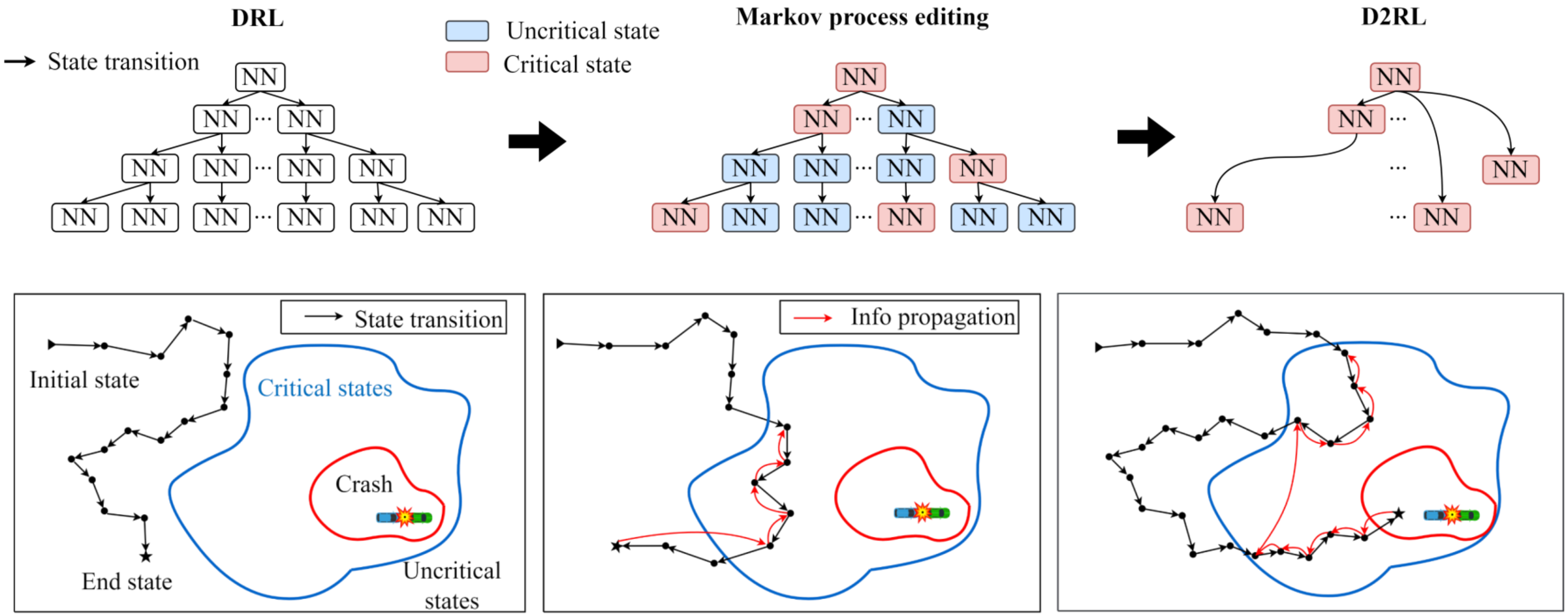
1 crash every  miles
1 injury every miles
1 fatality every miles

using <u>small number of testing miles</u>

Unbiasedness

Efficiency

Dense Deep Reinforcement Learning (D2RL)



Feng et al., 2023. Dense Reinforcement Learning for Safety Validation of Autonomous Vehicles. *Nature*, 615, 620-627.

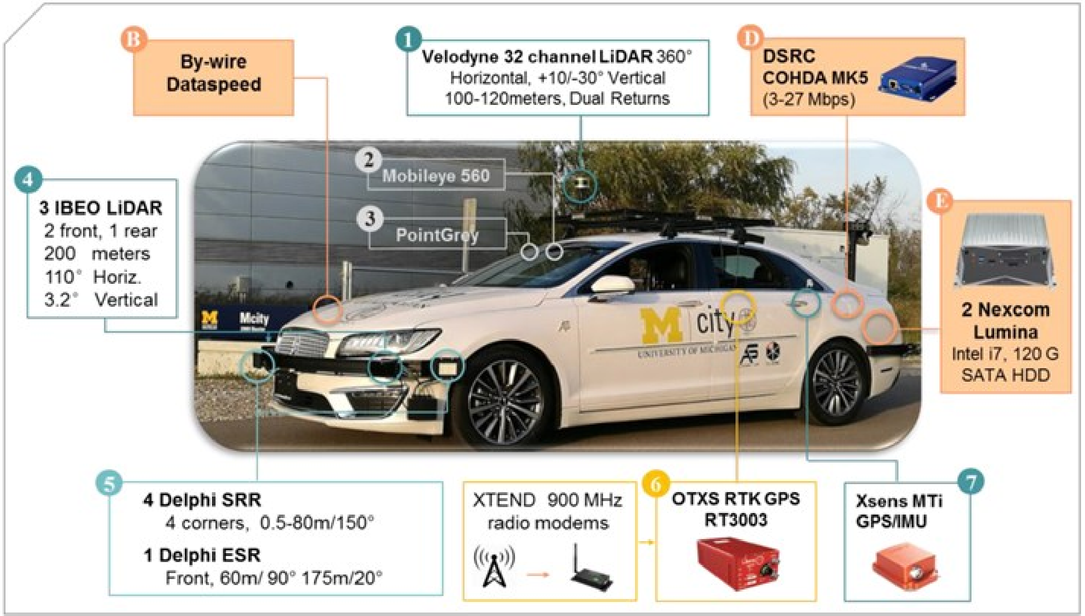
Long tail events in NADE

Adversarial Examples

(Feng et al., Nature Communications, 2021)

Safety Assessment for Autoware

Hardware stack: UM OpenCAV Platform



Software stack: Autoware.AI

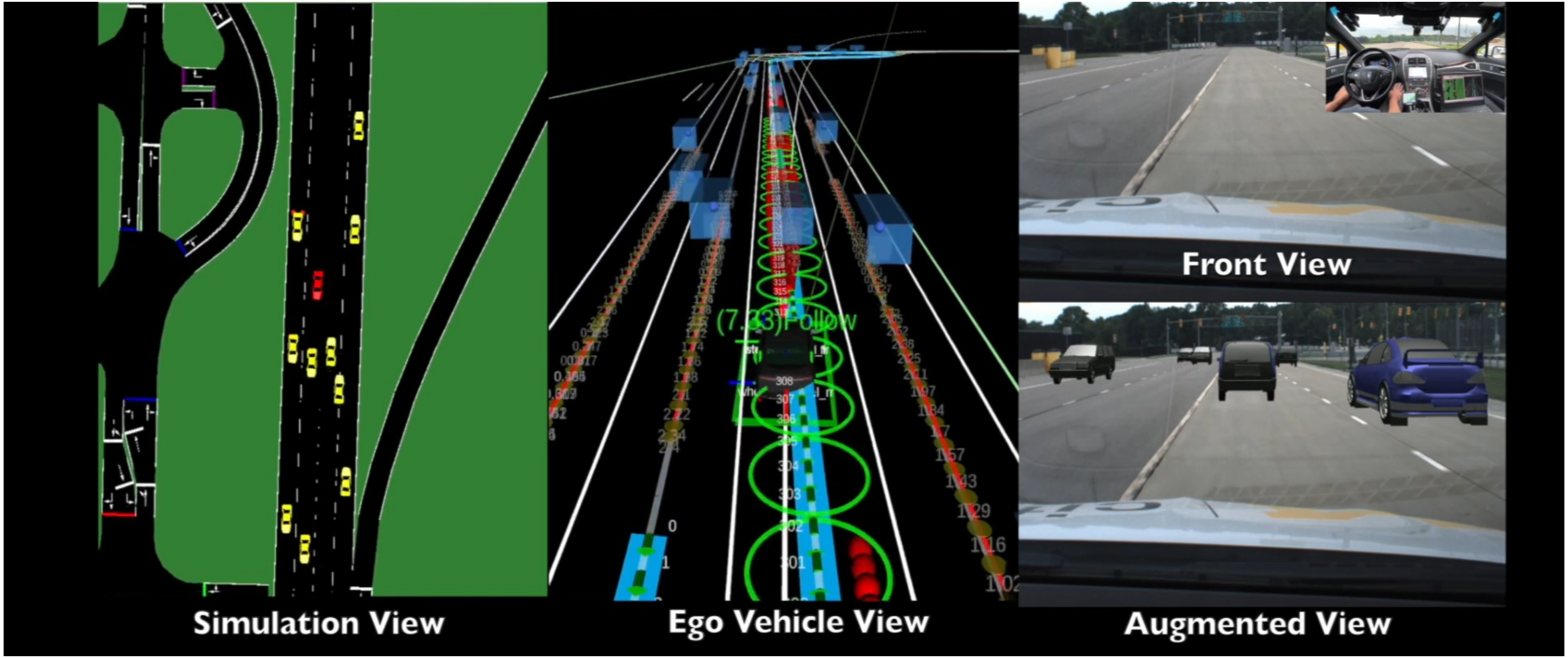
AutoWare

+

Robot Operating System (ROS)

ROS

Mcity Mixed Reality Test



Detroit ADS Demonstration Project

Office of Mobility Innovation to Launch Self-Driving Shuttle Pilot to Improve Quality of Life for Older Adults and People with Disabilities

JUL 26 2023

OFFICE OF MOBILITY INNOVATION

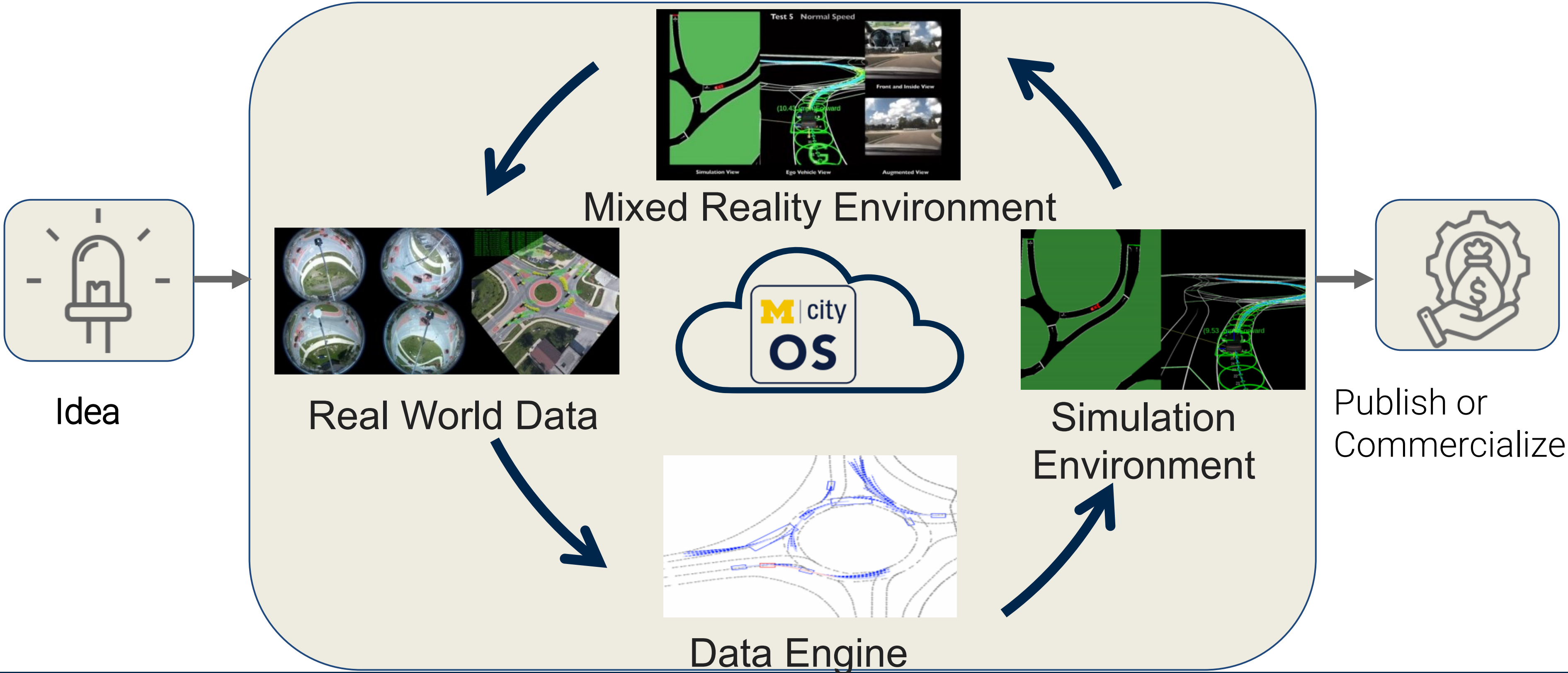
The self-driving shuttle will be tested through the Mcity Safety Assessment Program before deployment.

Mcity 2.0: A Makerspace for Mobility Innovations

Develop the Mcity Test Facility into a **fully autonomous, mixed reality, remote-capable facility**.

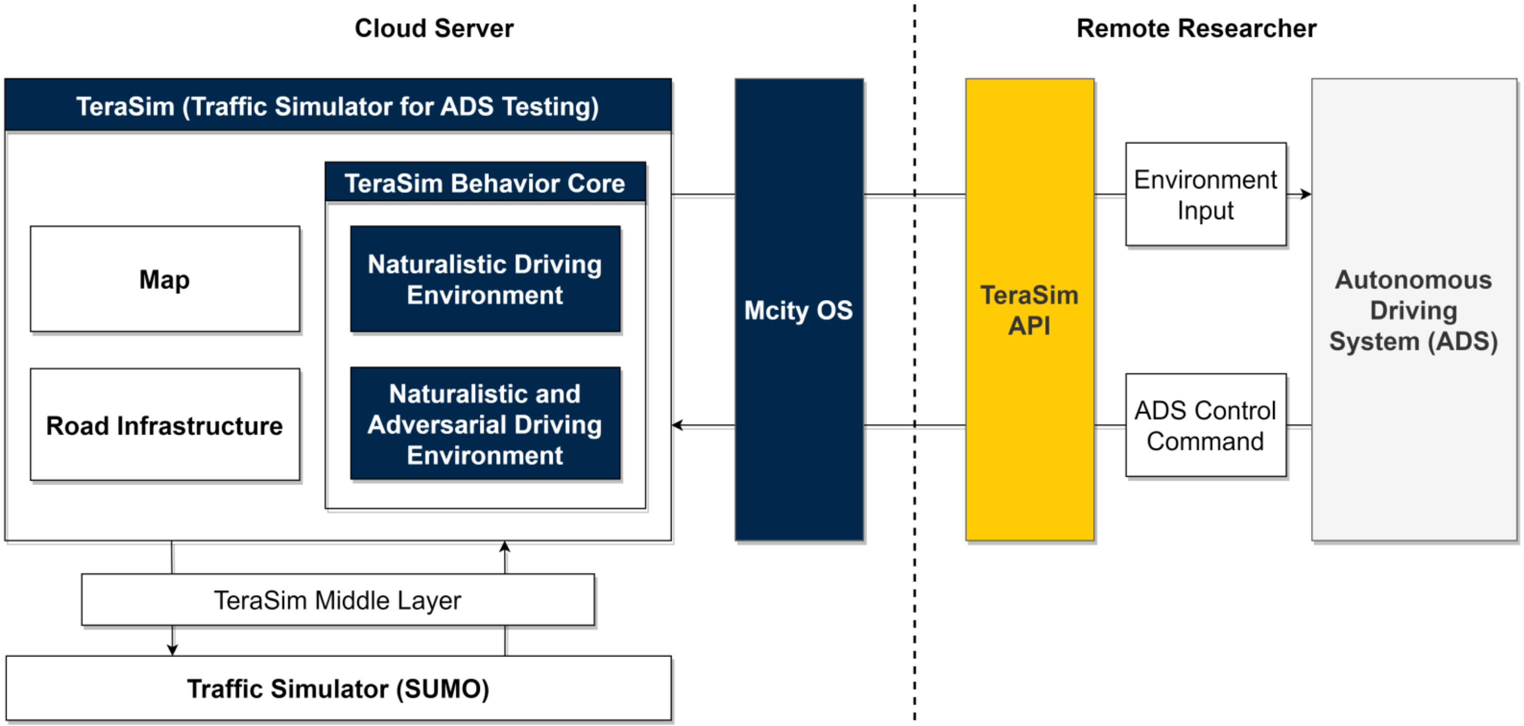
The focus of the project is to build digital infrastructure upon physical infrastructure for AV testing.

Mcity 2.0 From The Researcher’s Perspective



TeraSim

A cloud-based traffic environment simulator for testing autonomous vehicles



Remote Testing

AV Development and Testing is a Multidisciplinary Research Problem

Automotive Engineering

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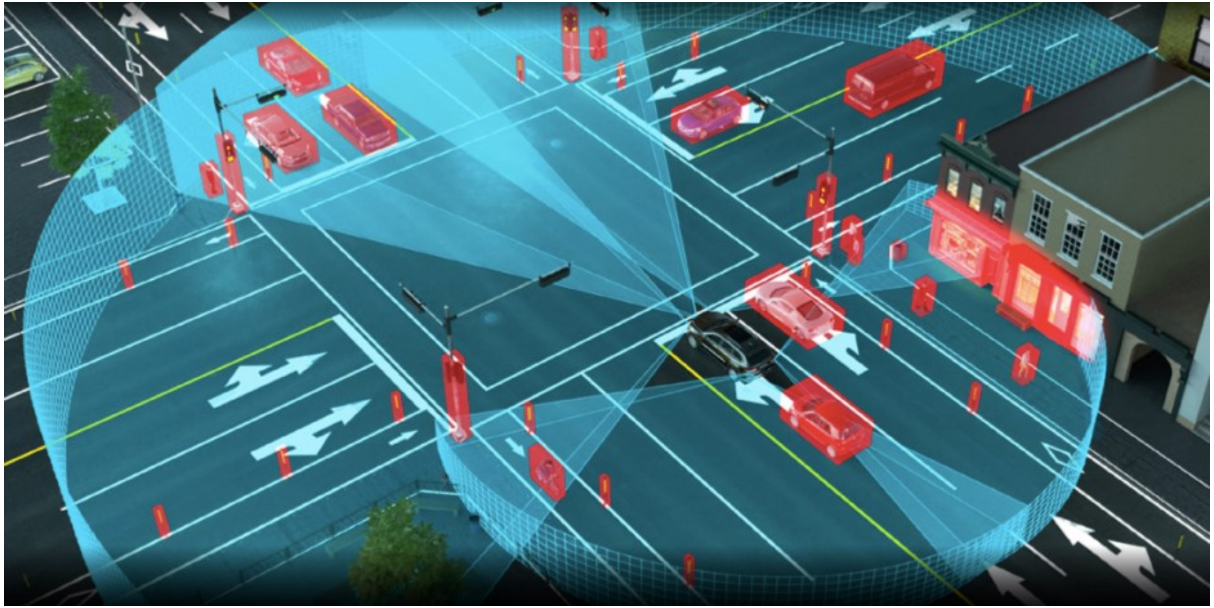
Artificial Intelligence

+

Transportation Engineering

- Both development and testing of automated vehicles need a **naturalistic driving environment**.



Selected Publications and Media Coverage

- Feng et al., 2023. Dense Reinforcement Learning for Safety Validation of Autonomous Vehicles. *Nature*, 615, 620-627.
- Yan et al., 2023, Learning naturalistic driving environment with statistical realism, *Nature Communications*, 14, 2037.
- Mims, C. How Will We Know When Self-Driving Cars Are Safe? When They Can Handle the World's Worst Drivers. *Wall Street Journal* (2023).

March 23, 2023 ***Nature***

nature communications

Article

https://doi.org/10.1038/s41467-023-37677-5

Learning naturalistic driving environment with statistical realism

Received: 20 September 2022

Accepted: 28 March 2023

Published online: 11 April 2023

Check for updates

Xintao Yan, Zhengxia Zou, Shuo Feng, Haojie Zhu, Haowei Sun & Henry X. Liu

For simulation to be an effective tool for the development and testing of autonomous vehicles, the simulator must be able to produce realistic safety-critical scenarios with distribution-level accuracy. However, due to the high dimensionality of real-world driving environments and the rarity of long-tail safety-critical events, how to achieve statistical realism in simulation is a long-standing problem. In this paper, we develop NeuralNDE, a deep learning-based framework to learn multi-agent interaction behavior from vehicle trajectory data, and propose a conflict critic model and a safety mapping network to refine the generation process of safety-critical events, following real-world occurring frequencies and patterns. The results show that NeuralNDE can achieve both accurate safety-critical driving statistics (e.g., crash rate/type/severity and near-miss statistics, etc.) and normal driving statistics (e.g., vehicle speed/distance/yielding behavior distributions, etc.), as demonstrated in the simulation of urban driving environments. To the best of our knowledge, this is the first time that a simulation model can reproduce the real-world driving environment with statistical realism, particularly for safety-critical situations.

2023 ***Nature Communications***

May 20, 2023 ***Wall Street Journal***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