Multiresolution Platform to Verify and Validate Cooperative Driving Automation Functionalities in Contested Environments

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Introduction

- **Education:**
  - MSc: Aerospace Engineering, University of Florida, 2019
  - PhD: Mechanical Engineering, University of Florida, 2020
  - BSc, MSc, PhD: Electrical Engineering-control systems, 2010, 2012, 2015
- **Current position:**

  Assistant Professor of Mechanical Engineering
- **Research Interests:**

  Security of Networked Control Systems; Testing and verification of Connected and Autonomous Vehicles; Security of Multi-agent Systems
- **Previous positions:**
  - Assistant Professor of Electrical and Computer Engineering, Florida Polytechnic University
  - Director of Advance Mobility Institute, Florida Polytechnic University
  - Research Assistant Professor, Florida International University
  - System Development Engineer, PLC International Inc

RANCS Team

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Nathan Gardner

Introduction

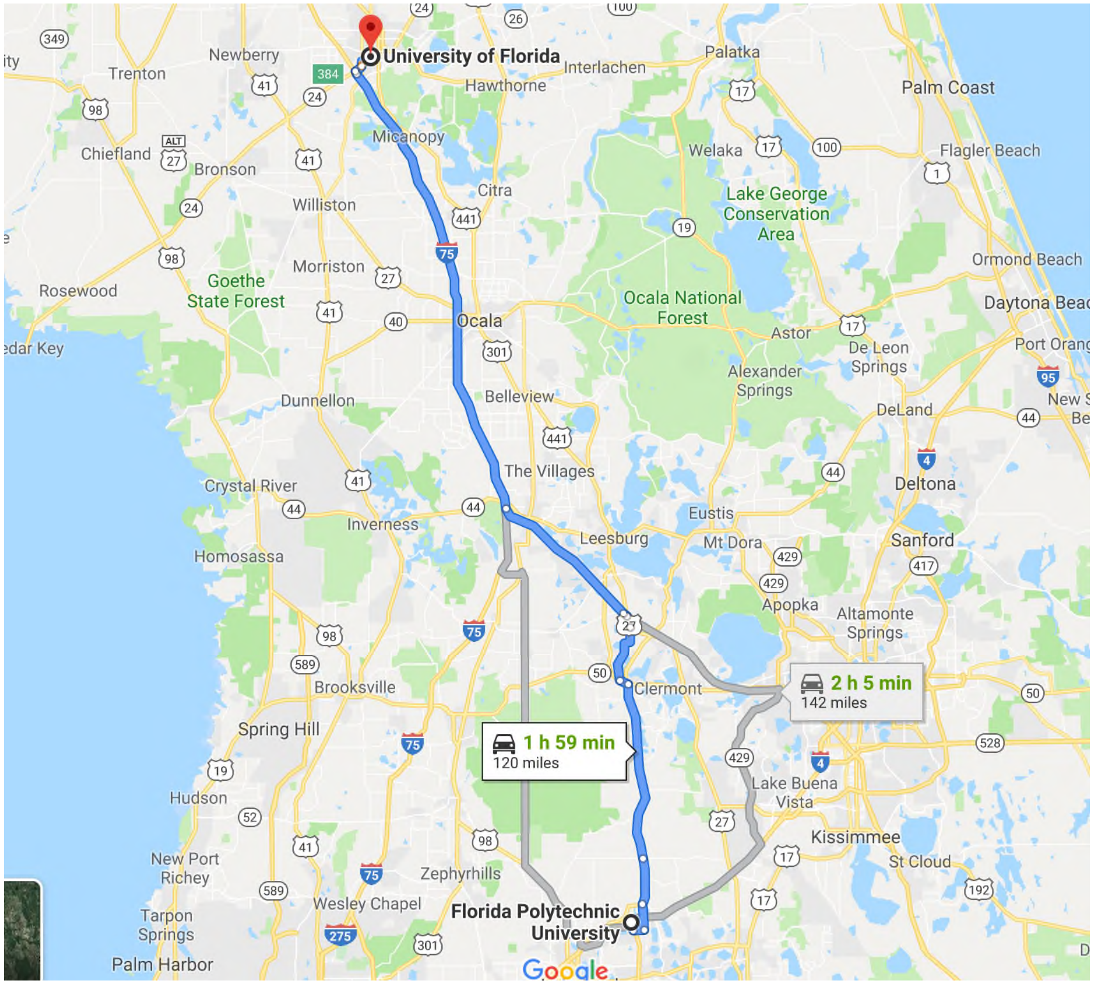
- According to a report of the National Highway Traffic Safety Administration (NHTSA), **94 percent of the 37,461** traffic fatalities in 2016 were due to human error.
- Autonomous Vehicles (AVs), including marine and robots, have the potential to add great value, but to be effective, they must be shown to be **safe and secure**.

Source: https://www.texastribune.org/2015/07/07/google-testing-self-driving-vehicles-austin/

Autonomous Vehicles

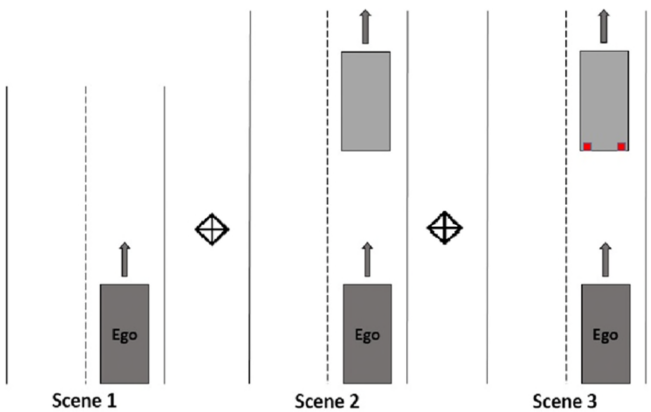
- Despite all of AV's advantages, the major barrier for wide-scale adoption of AVs is **the test and verification** regime to safety and security.

- To address this barrier, a process, which builds an *engineering argument* for assuring **safety and security**, must be developed.



Challenges

- **Scenario Testing and Verification**
  - How to generate interesting edge cases?
  - Do we need to test for all possible cases?
  - Can we eliminate similar scenarios using equivalent classes theory?
  - Can we do the coverage analysis?



- **Developed a language of factors that define a scene**
- **Factors translated into parameters for formulation**
- **Formulation enables pseudo-random test generation**

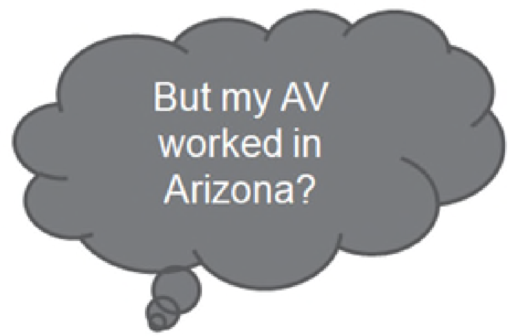
$$\left(\begin{bmatrix}0&0&0&0&0\\0&1&0&0&0\\0&0&0&0&0\\0&0&0&0&0\\0&0&0&0&0\end{bmatrix}\begin{bmatrix}1&0&0&0&0\\0&1&0&0&0\\0&0&0&0&0\\0&0&0&1&0\\0&0&0&0&0\end{bmatrix}\begin{bmatrix}1&0&0&0&0\\0&1&0&0&0\\0&0&0&0&0\\0&0&0&1&0\\0&0&0&0&0\end{bmatrix}\right)\begin{bmatrix}d_{rlong}\\V_{rel}\\d_{rlat}\\d_{long}\\d_{lat}\end{bmatrix}=\begin{cases}pass\ if\begin{cases}d_{rlong}\geq 0\\V_{rel}>0\\d_{long}>0\end{cases}\\fail\quad Otherwise\end{cases}$$

Challenges

- **Scenario Testing and Verification**
  - How can we systematically learn from real-world crashes?
  - Can we test future CAVs based on real-world crashes?

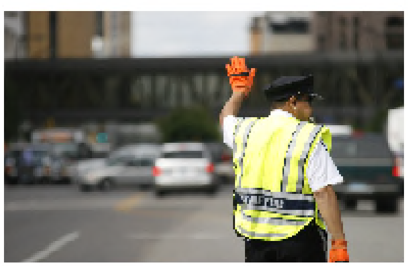
Challenges

- **Environmental and sensor testing**
  - How the perception of CAV performs under electromagnetic interferences?
  - How to test CAVs and their perception under different weather conditions?



Challenges

- **Language of Driving**
- Do we have a language for driving?
- How human in the loop can be tested?
- How ethical are CAVs?




Security Challenges

- Cyber-physical attack
  - How to test the security of CAVs in critical situations?
  - How to test the stability of CAVs under faults, failures, and cyber-physical attacks?

Challenges:

- Cost of redesign and collaboration problem
- Random attacks
- Resource constraints
- Communication protocols are not well designed
- Intelligent attacks

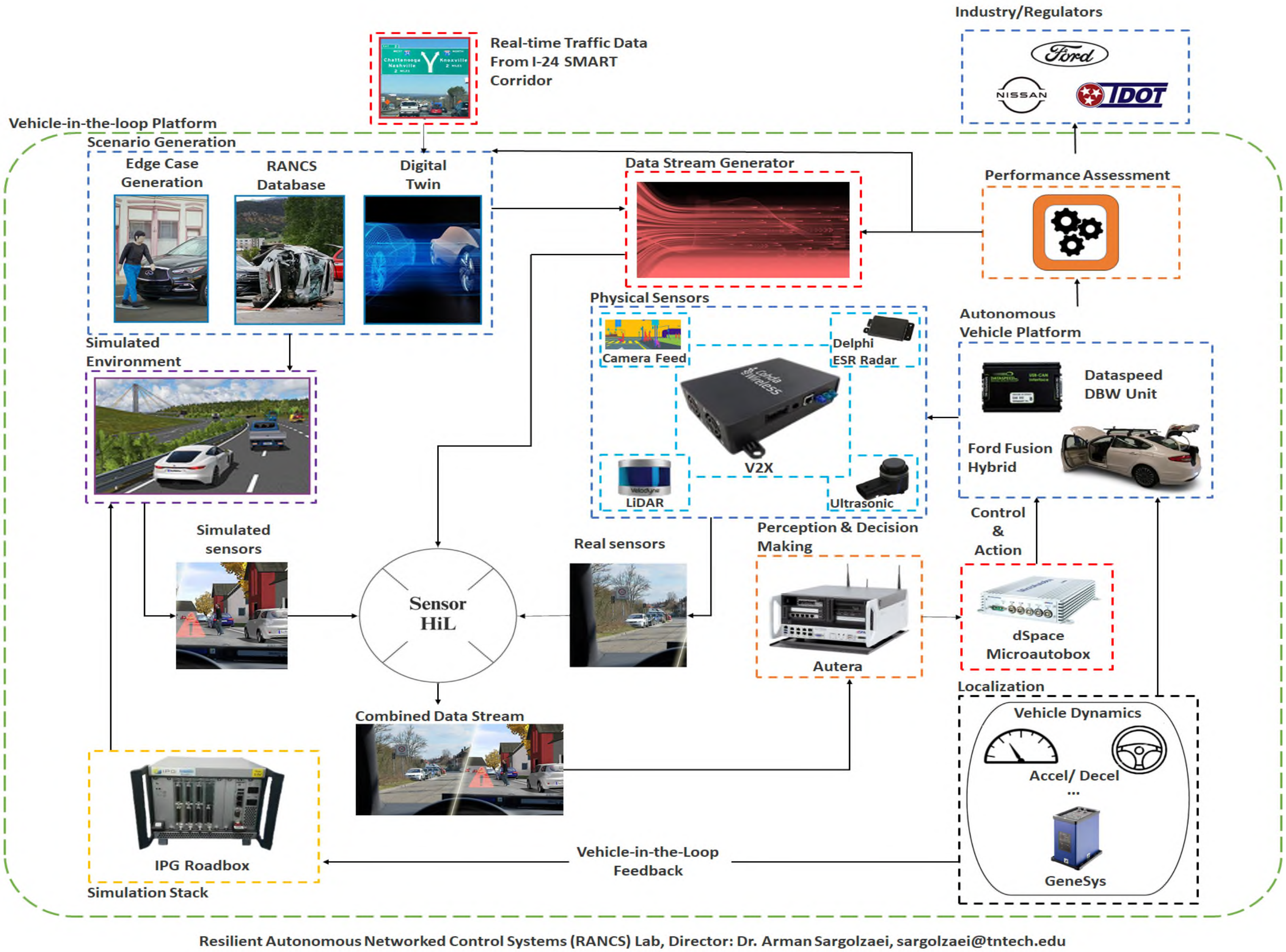
Testing Environments

Offline testing
- Software-in-the-loop

Real-time testing
- Software-in-the-loop
- Hardware-in-the-loop

Real-time testing
- Vehicle-in-the-loop
- Real-world

Mixed Reality Platform



Modes of operation:

- Manual
- ViL
- Automated
- Autonomous Level 3+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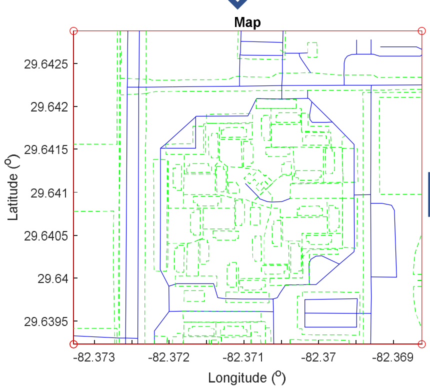
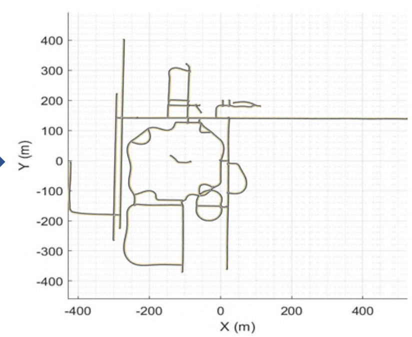
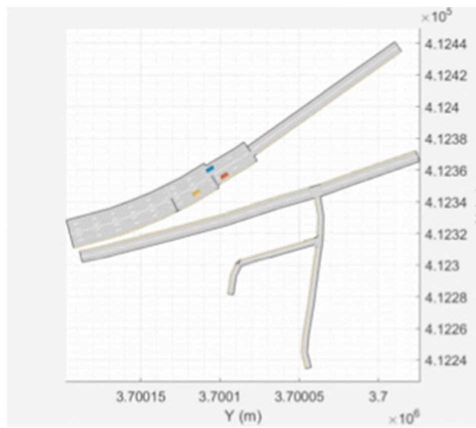
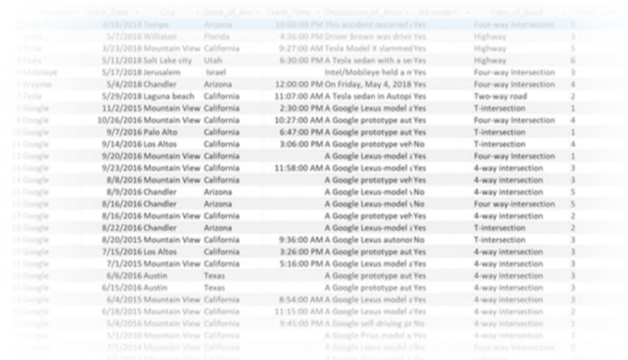
Scenario Generation

- Game engines and random scenario generation (coverage and equivalent Classes)
- Scenario abstraction from real life
- Digital Twin Environment

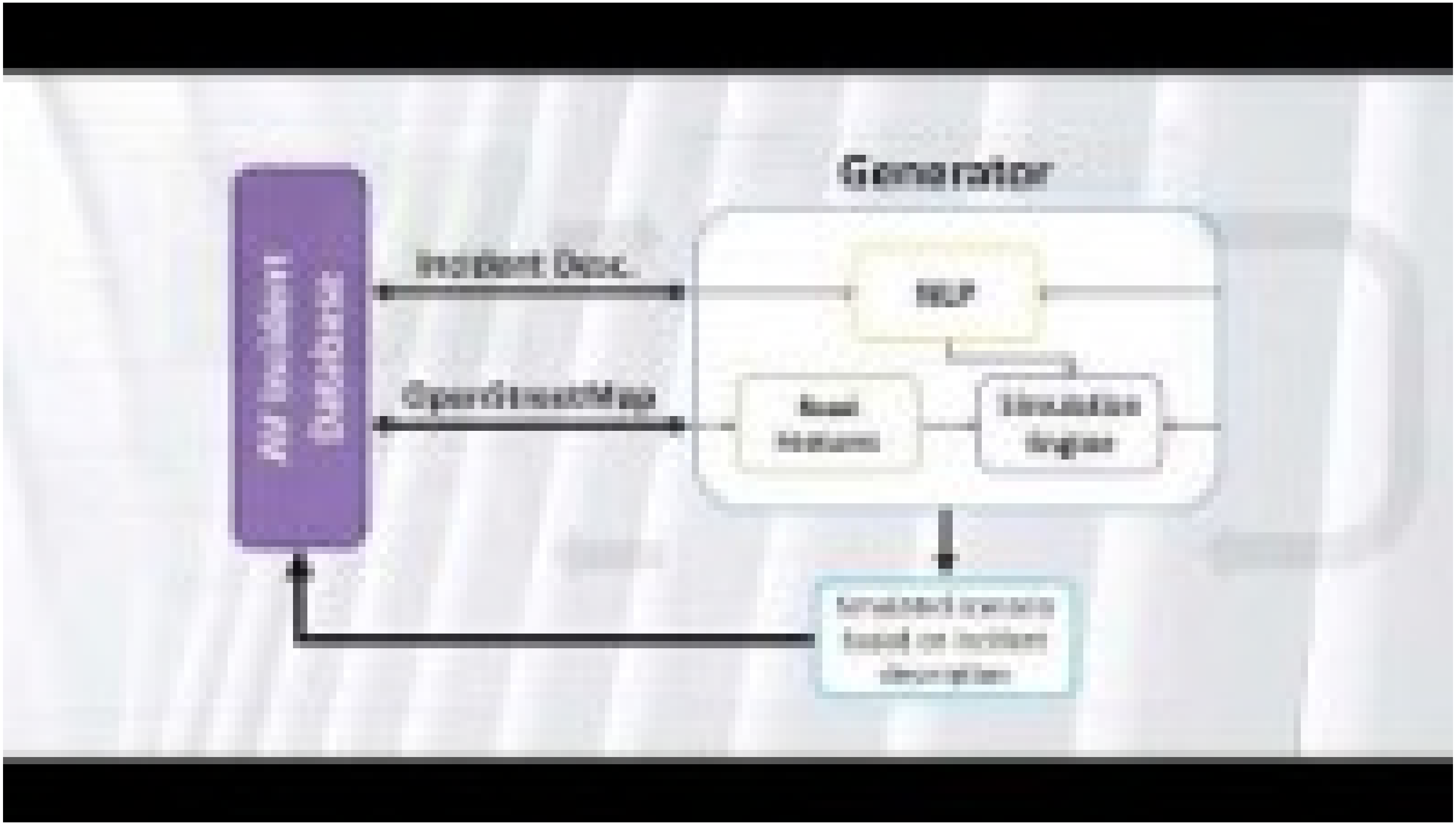




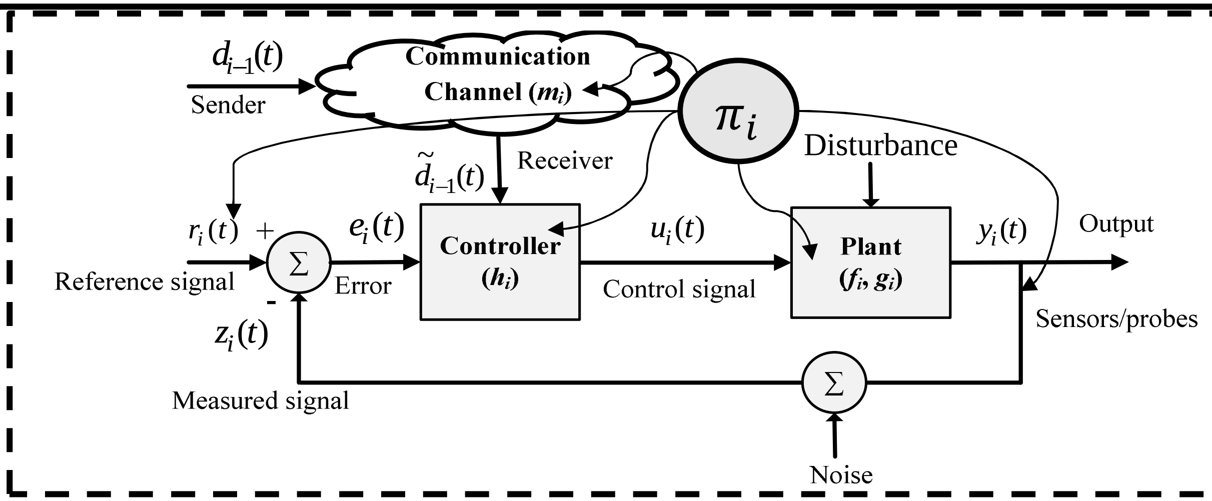




Scenario abstraction from real crashes



Attack and Fault Generation



Effects of attack π_i can be modeled as

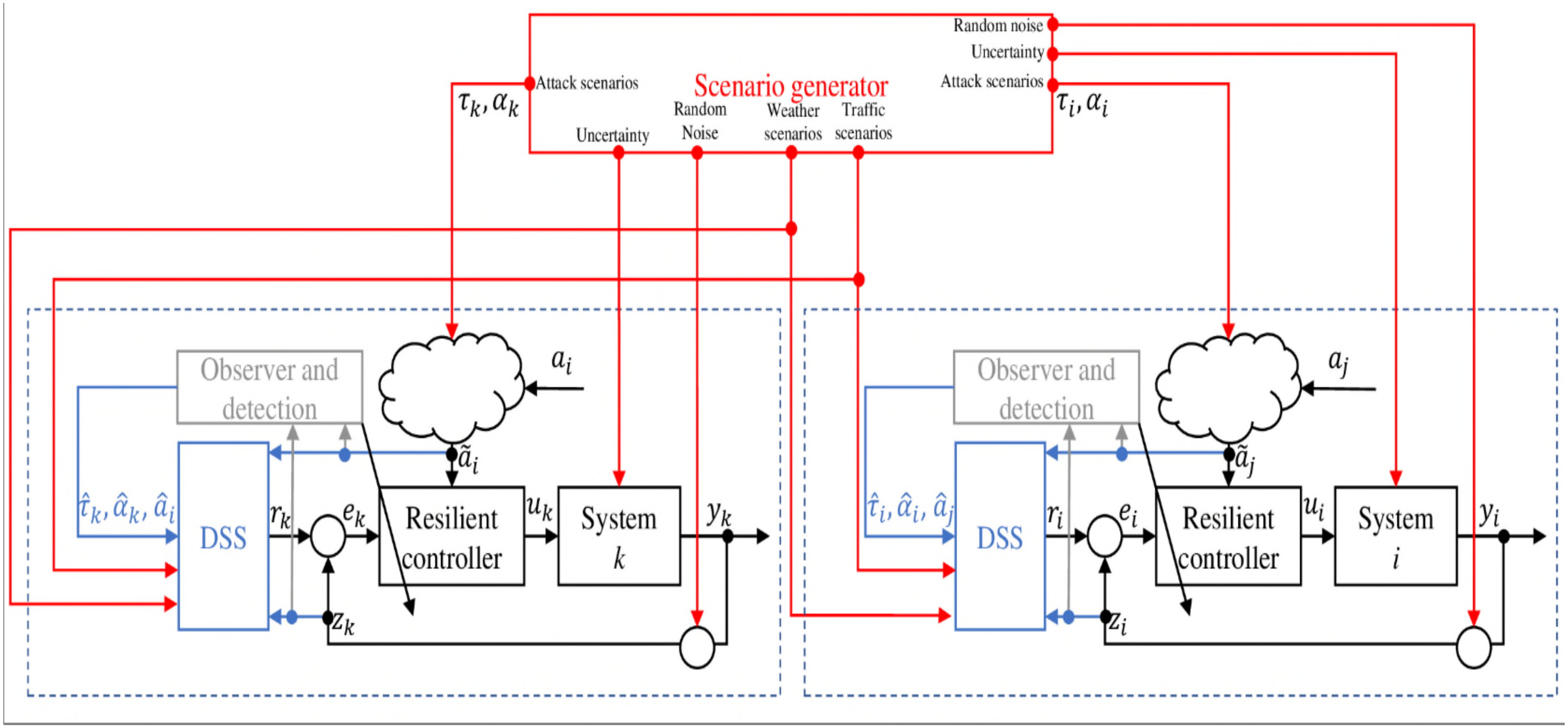
$$\tilde{\gamma}_i(t) = \pi_i(\gamma_i(t)) = \gamma_i(t - \tau_i(t)) + \beta_i(t)$$

where β_i and τ_i are random variables, γ is the signal/information under attack.

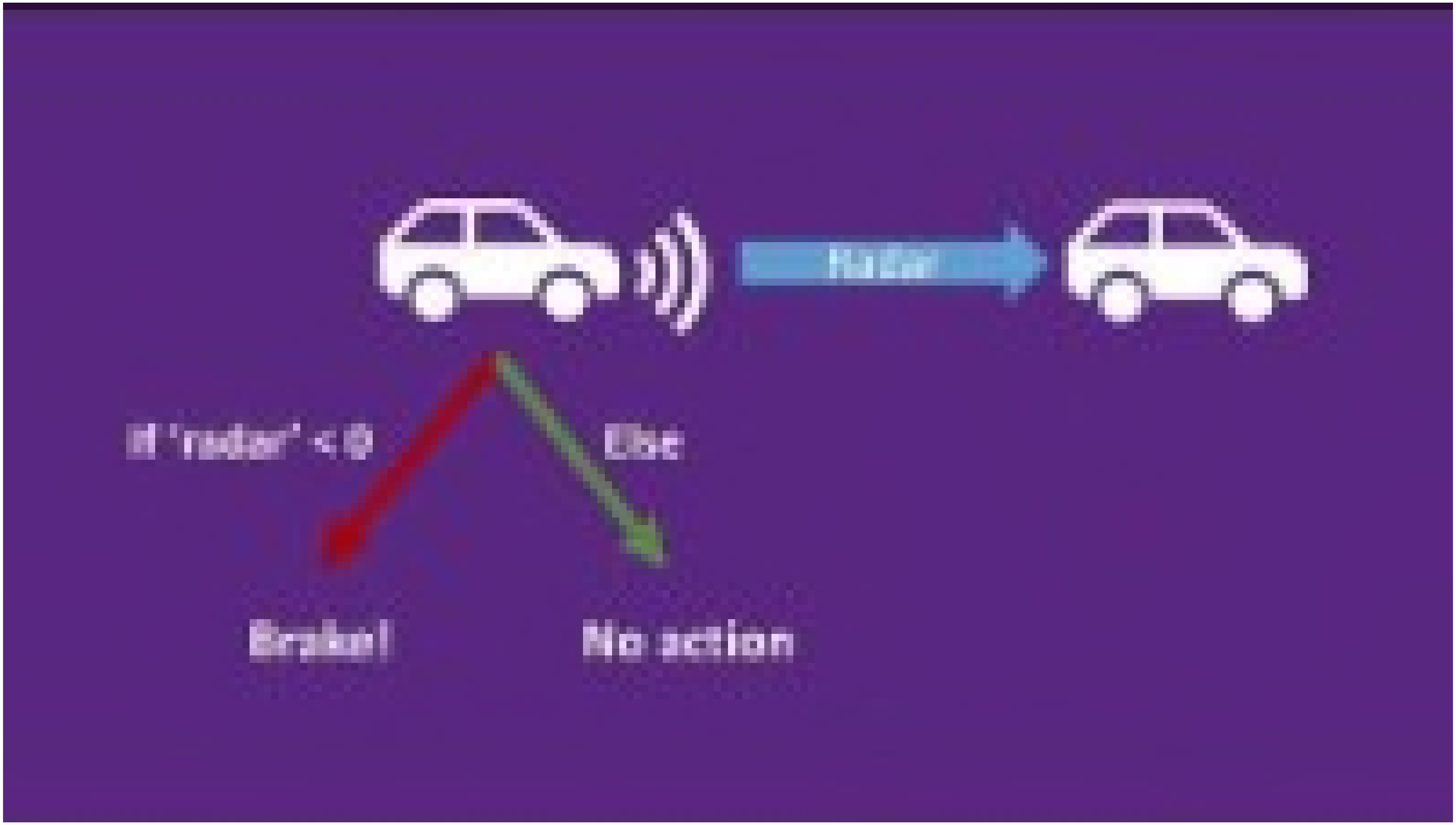
- **False Data Injection (FDI) Attack:** $\tau_i = 0$ and $\beta_i \neq 0$ for $t \geq 0$
- **Time-Delay Switch (TDS) Attack:** $\tau_i \geq 0$ and $\beta_i = 0$ for $t \geq 0$

The proposed model covers weather effects on sensors and vehicle communication.

Attack and Fault Generation



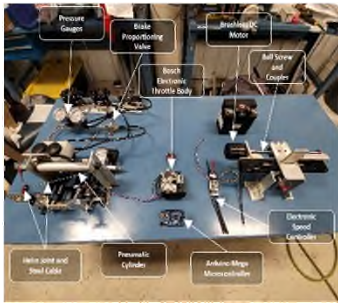
CAV under Attack



Autonomous Race Vehicle

Our Research:

- Testing and Verification of CAV
- Testing V2P interactions
- Testing and training human and CAV interactions
- Digital Twin and Mixed Reality Platform
- Drive by Wire Table for Racing Vehicle
- Autonomous Racing Vehicle
- Autonomous Golf Cart
- Vehicle Simulator



Towards Autonomoy

Q/A

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