Agenda

• Background
  – Connected and Automated Vehicles (CAV)
  – Hardware in the Loop (HIL) Testing in Transportation
  – Platooning Proof-of Concept Case Study

• STARS Methodology
  – Experiment Phases
  – Virtual Transportation Simulation
  – Small-Scale Vehicle

• Analysis
  – Vehicle Parameters
  – Data Analysis

• Conclusions
  – Findings
  – Future Work
Background: CAVs

- Connected and Automated Vehicles (CAV)
  - A connected vehicle is equipped with wireless access allowing for shared data between other devices, infrastructure, and other vehicles
  - An automated vehicle is capable of sensing and navigating its environment without human input

- Platooning Proof-of Concept Case Study
  - Full-scale production vehicles outfitted with aftermarket sensors attempted Platooning through Cooperative Adaptive Cruise Control (CACC)
Background: CAVs

- Platooning Proof-of-Concept Case Study
  - Full-scale production vehicles outfitted with aftermarket sensors using longitudinal commands for vehicle for CACC

- Outcome
  - Platooning achieved through CACC
  - Verification and validation techniques observed for future work

*CACC Diagram*
Background: HIL in Transportation

• Hardware in the Loop (HIL)
  – Hybrid of hardware and software components

• Previous Case Study
  – U.S. Department of Transportation (DOT) National Highway and Traffic Safety Administration (NHTSA) Vehicle Research Test Center (VRTX)
  – Pneumatic braking system used by DOT for heavy truck braking

• Outcomes
  – Metrics to determine system benefits by linking crash data from national databases
  – A new methodology to determine safety benefits on technology with limited exposure to data
STARS Methodology: Experiment Phases

**Phase 1**
- Create a simulated driving scenario in VISSIM and conduct cycles of the scenario to amass a large data set

**Phase 2**
- Conduct field tests physically mimicking the simulated driving scenario to gather real-world, small-scale data from the physical platform

**Phase 3**
- Compare simulated data with real-world test data to calibrate a model of vehicle variables
• Driver Behavior Model
  
  - Intelligent Driver Model (IDM) used for CACC modeling
  - CACC simulation used for Leader-Follower Platooning Scenario

\[
a_{IDM}(s, v, \Delta v) = \frac{dv}{dt} = a[1 - \left(\frac{v}{v_o}\right)^\delta - \left(\frac{s^*(v, \Delta v)}{s}\right)^2]
\]

where: \( s^*(v, \Delta v) = s_o + vT + \frac{v\Delta v}{2\sqrt{ab}} \)
STARS Methodology: Small-Scale Vehicle 1 of 2

• STARS Architecture

  – Path planning executable written as a control loop developed in the Ground Control Station (GCS)
  – Path planning executed and later compared to VISSIM IDM model
  – Generalized formula for Proportional-Integral-Derivative (PID) Control Loop:

\[ u(t) = K_p e(t) + K_i \int_0^t e(t') dt' + K_d \frac{de(t)}{dt} \]
• STARS System Diagram and GCS Overlay

**STARS Vehicles**

**Ground Control Station Software**

![Diagram showing STARS system and GCS overlay](image-url)
Analysis: Vehicle Parameters

- Modern Control Theory used for Platooning simulation
- Generalized PID loop used:
  \[ u(t) = K_p e(t) + K_i \int_0^t e(t') dt' + K_d \frac{de(t)}{dt} \]
Comparison of VISSIM and Field Test Data

Graphic Reflects Data Obtained from Follower Vehicles in VISSIM and Field Tests
Conclusion: Findings

• Live field tests used GPS localization for Leader-Follower Model
• Leader-Follower path planning algorithms of vehicles that use automated longitudinal control was demonstrated in simulation
• Follower Model used Proportional-Integral (PI) control loop for waypoint navigation
• Proof-of-concept HIL using commercial off-the-shelf (COTS) equipment
Conclusion: Future Work

- Small-scaled HIL has potential to test orphan technologies or payloads by avoiding costly integration on fielded system
- COTS equipment for HIL could be used as an intermittent step for vehicle Verification and Validation
- STARS complements the scope and purpose of current U.S. Army Robotic Enhancement Program (REP) and Applied Robotics for Installations and Base Operations (ARIBO) initiatives
  - Helps efficiently identify opportunities as part of autonomy strategy in resource-constrained environment
  - Allows for simultaneous systems testing and Verification and Validation while generating business case for particular autonomous technology/function through low-cost, rapid deployment
Thank You

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