Introduction

Background
- CAVs can improve efficiency of transportation systems, e.g., stabilizing platoons in mixed traffic conditions.
- Understanding & simulating HDVs behavior -- essential if one seeks to use CAVs to realize such benefits.
- Increasingly availability of microscopic traffic flow (MTF) data has increased feasibility of MTF models for this purpose.

Research Objectives
- To analyze characteristics of NGSIM empirical trajectory dataset.
- To calibrate MTF models of HDVs using NGSIM datasets, considering heterogeneity and uncertainty of human drivers behavior.
- To design CAV controllers based on real-time calibrated HDV dynamics to stabilize mixed traffic platoon.

Methodology

Proposed Controller Design (CD) Framework
- Data filtering: deal with noises artifacts in NGSIM data.
- Inventory of HDV behavior models: sample HDVs dynamics
- The CD problem -- formulated as an optimization problem aimed to increase safety and efficiency of the stabilized mixed traffic platoon.

Data Preparation
- Vehicle trajectory data was acquired through digital video processing; data contains some noise.

Model Calibration
- To simulate the dynamics of HDVs: Full velocity difference model (FVDM) considering time delay, is used:
  \[ \dot{x}_i(t) = a_i \left( v_i (\Delta x_i (t - t_i) - x_i (t - t_i)) + \beta_i d v_i (t - t_i) \right) \]
  Parameter space, \( \Theta_i = \{a_i, b_i, \beta_i, \eta, m, \tau_i\} \).
- The errors to be minimized in the calibration are:
  \[ F(x) = \frac{1}{ \| \text{data} \|} \left( \text{data} - F(x) \right)^2 \]
  where \( s(t) = x_{i-1}(t) - x_i(t) \); operator \( \| \cdot \| = \int_0^T s(t) dt \).
- GA algorithm is used to estimate the parameter \( \Theta_i \) characterizing the car-following model, for each vehicle.
- Initialization: \( x \text{data}(\theta) = x_{\text{data}}(\theta) = v_{\text{data}}(\theta) \).
- Update rule:
  \[ x_i^{\text{sim}}(k) = x_i^{\text{sim}}(k-1) + v_i^{\text{sim}}(k-1) + \frac{1}{2} a_i(k) dt^2 \]
  \[ v_i^{\text{sim}}(k) = v_i^{\text{sim}}(k-1) + a_i(k) dt \]

Results (Continued)

Controller Design
- The CAV controller design problem can be formulated as a multi-objective problem with the following objectives:
  - maximize the nr. of HDVs that the CAV can stabilize, given a set of oscillations that may trigger stop-and-go waves
  - minimize collision risk (maximize safety)

Numerical Experiment
- To test the performance of the controllers designed in this study, we used models calibrated using NGSIM dataset to serve as a population and sample HDV dynamics from the inventory.

Conclusion & Summary
- Study proposes a framework to (a) describe the dynamics of HDVs and (b) design CAV controllers for traffic stabilization based on calibrated Microscopic Traffic Flow models of HDVs.
- Study tested the proposed framework using NGSIM dataset. Due to artifact noises in the empirical trajectory data, filtering and smoothing were found to be necessary prior to the model calibration.
- The framework was found to be capable of handling mixed stream (HDVs + CAVs), because the model captures HDV real-time dynamics.