Multi-objective Optimization Controller for Cooperative Adaptive Cruise Control

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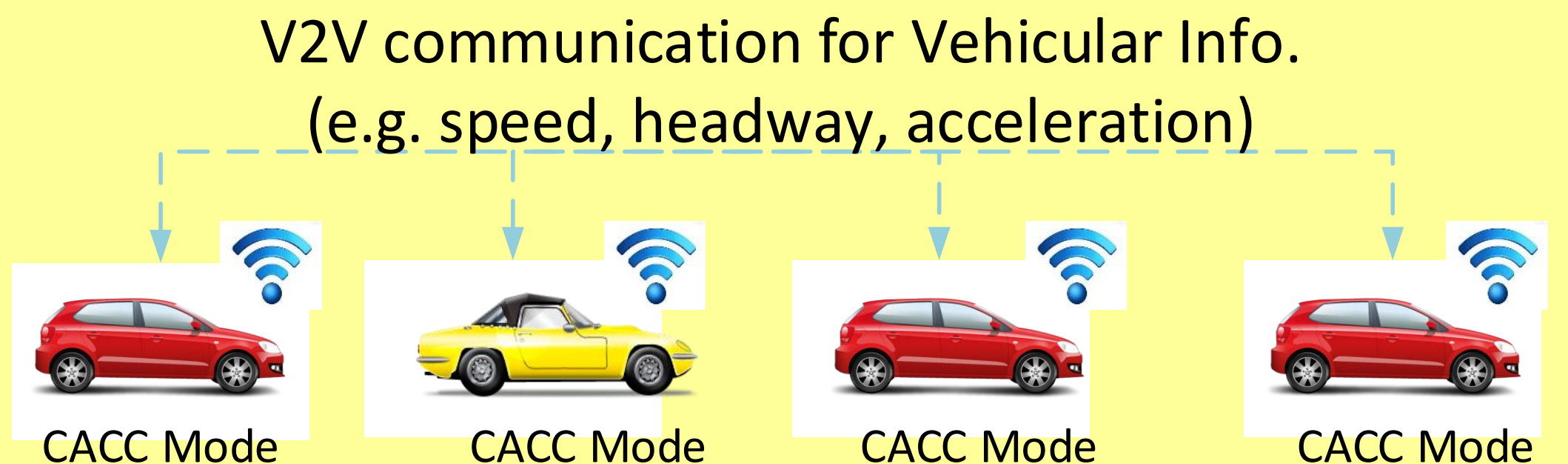
Introduction

Since the USDOT's announcement of the Connected Vehicle (CV) initiative in 2002, automated longitudinal vehicle control technology has gained increasing attentions. Cooperative Adaptive Cruise Control (CACC), as an evolved control schema of currently available ACC in the market, was made possible under CV environment by adding an extra communication layer where equipped vehicles are capable of exchanging their instantaneous driving information (e.g. position, speed, and acceleration rate).



This study puts forward a multi-objective optimization (MOOP) CACC simulation framework by employing MATLAB genetic algorithm (GA) optimization toolbox. Microscopic simulation test bed was developed using VISSIM. Under the assumption of perfect V2V communication environment at this, the instantaneous vehicular information, collected by VISSIM COM interface, was fed into the MOOP controller, which in return provides optimal acceleration for each individual vehicle within a platoon in each CACC updating interval.

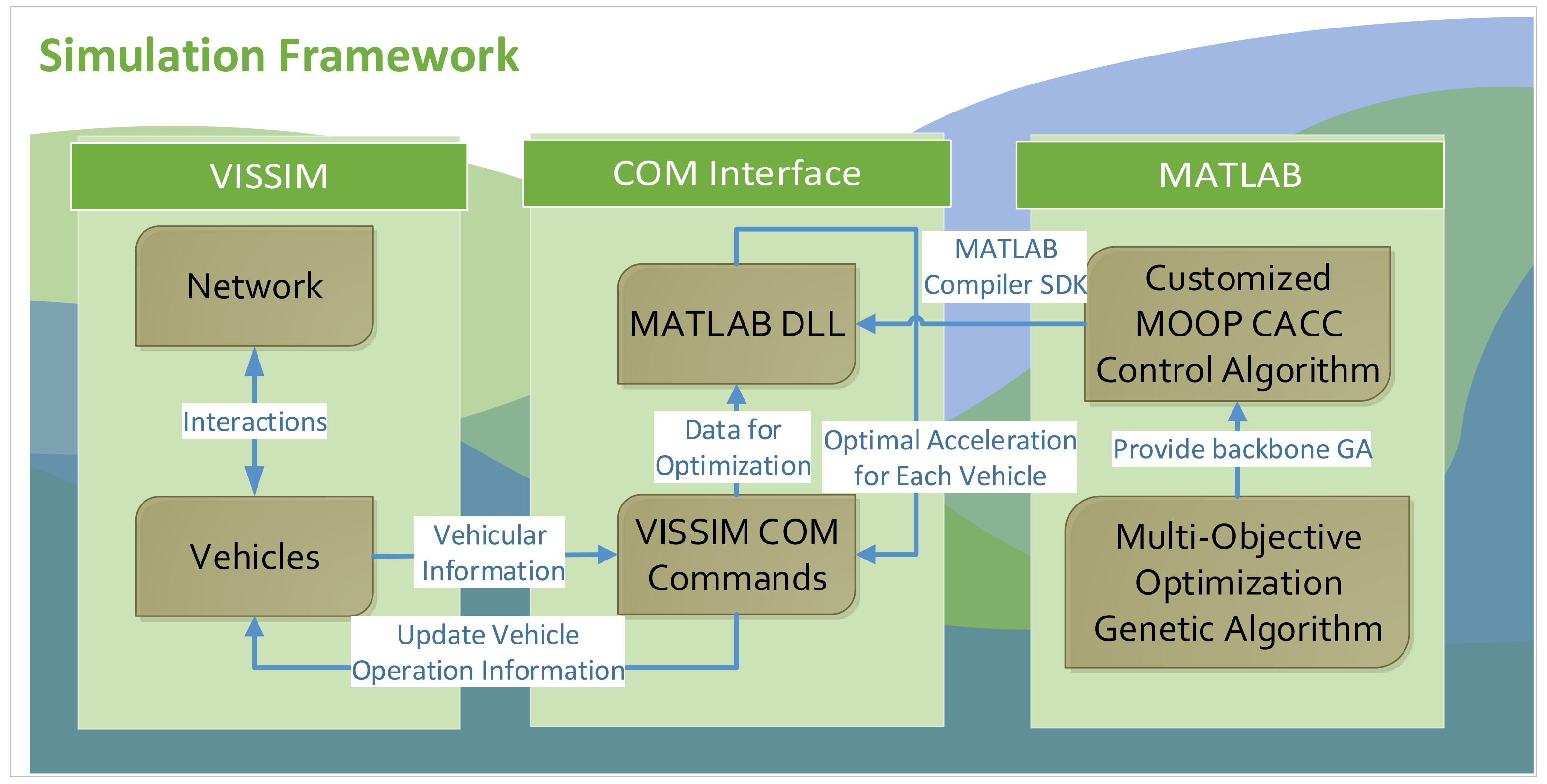
Advantages of CACC

- V2V communication of vehicular information among neighboring equipped vehicles
- Greater string stability compared to ACC
- Enhanced mobility and safety performance
- More comfortable riding experience

Research Objective

- To develop a multi-objective optimization algorithm for optimal intra-platoon vehicular control
- To build a simulation test bed that suits CACC evaluation as well as other CV applications
- To validate the performance of the proposed multi-objective control algorithm.

Simulation Test Bed



Multi-objective Optimization

Multi-objective Genetic Algorithm (GA) was employed to solve the optimization problem, which is comprised of **four objectives**:

- Target Headway Deviation

$$\sum_{i=1}^{n}\left|H-h_i(t)\right|$$

- Critical Following Condition

$$\sum_{i=1}^{n} e^{\frac{h_{i,0}}{h_i(t+1)}} \bullet \triangle v_i^{\,2}$$

- Vehicular Jittering

$$\sum_{i=1}^{n} e^{\beta\frac{|u_i(t+1)-u_i(t)|}{u_{comfort}}}$$

- Fuel Consumption

$$\begin{cases} \exp^{\sum_{i=0}^{3}\sum_{j=0}^{3}(L_{i,j}^{e}\times u^i\times a^j)} & \text{for } \alpha \ge 0 \\ \exp^{\sum_{i=0}^{3}\sum_{j=0}^{3}(M_{i,j}^{e}\times u^i\times a^j)} & \text{for } \alpha < 0 \end{cases}$$

Subject to

- Collision Avoidance

$$\frac{x_i(t+1)}{v_i(t+1)} \ge \gamma h_{i,\min}$$

- Effective Platoon

$$\frac{x_i(t+1)}{v_i(t+1)} \le h_{\max}$$

- Vehicle Powertrain

$$u_{i,\min} \le u_i \le u_{i,\max}$$

- Roadway Geometry

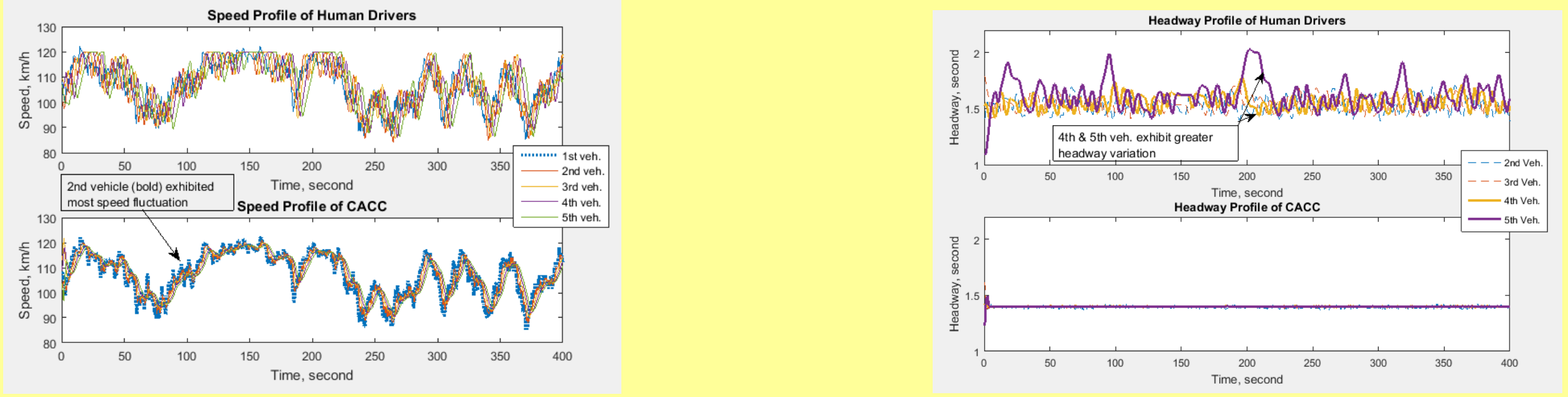
$$v_{\min} \le v_i \le v_{\max}$$

Proof-of-Concept Test

Under the assumption of perfect wireless V2V communication, we used a hypothetical one-lane freeway segment to conduct the simulation test. VISSIM built-in driving model was considered as human driver for comparison. The leading vehicle was controlled by a per-defined speed profile.

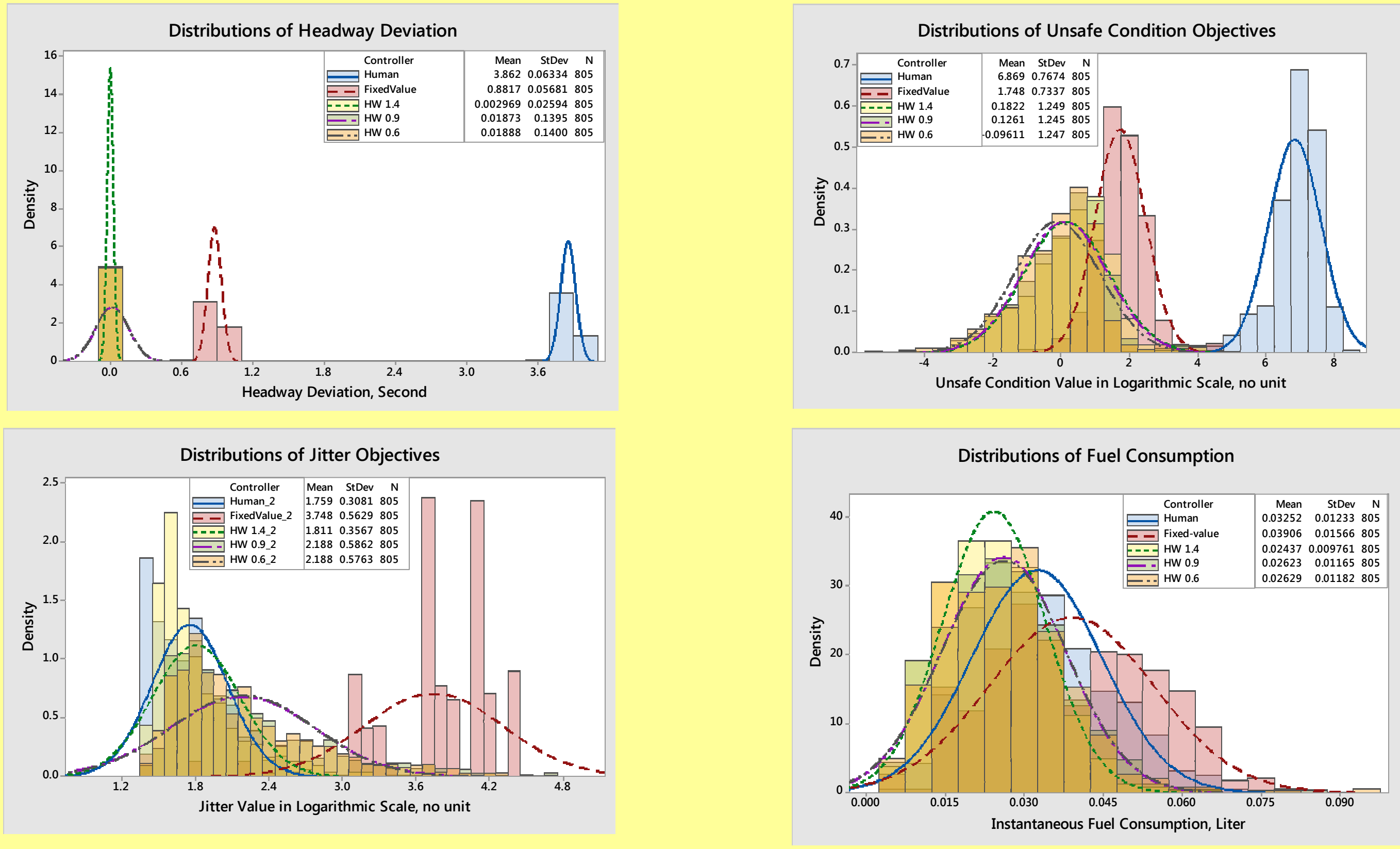
Preliminary Results

Vehicular Platoon Behaviors Comparison



Controller	vehicle	Mean (second)	Difference to Target Headway	Std. Deviation
MOOP-CACC	4th vehicle	1.3997	-0.0003	0.00254
	5th vehicle	1.3999	-0.0001	0.00820
Human	4th vehicle	1.5585	0.1585	0.0685
	5th vehicle	1.6191	0.2191	0.1323

Objective Value Comparison



Conclusions

Preliminary results show the MOOP CACC controller

- is able to converge to a set of optimal acceleration rates for the entire platoon in each iteration
- can greatly improve string stability by maintained the targeted headway under disturbances
- is also suitable for evaluations of other CV applications

Future Research

- Test the MOOP CACC algorithm in a realistic network
- Explore different deployment strategies (e.g. HOV-priority access, dedicated lane)
- Evaluate the algorithm under imperfect wireless communication environment (e.g. package drop)