NSF REU Site on Secure, Accessible, and Sustainable Transportation: Summer 2024

Integration of Connected and Autonomous Vehicles into Traffic: Sequential Truck Platoon Formation

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Abstract

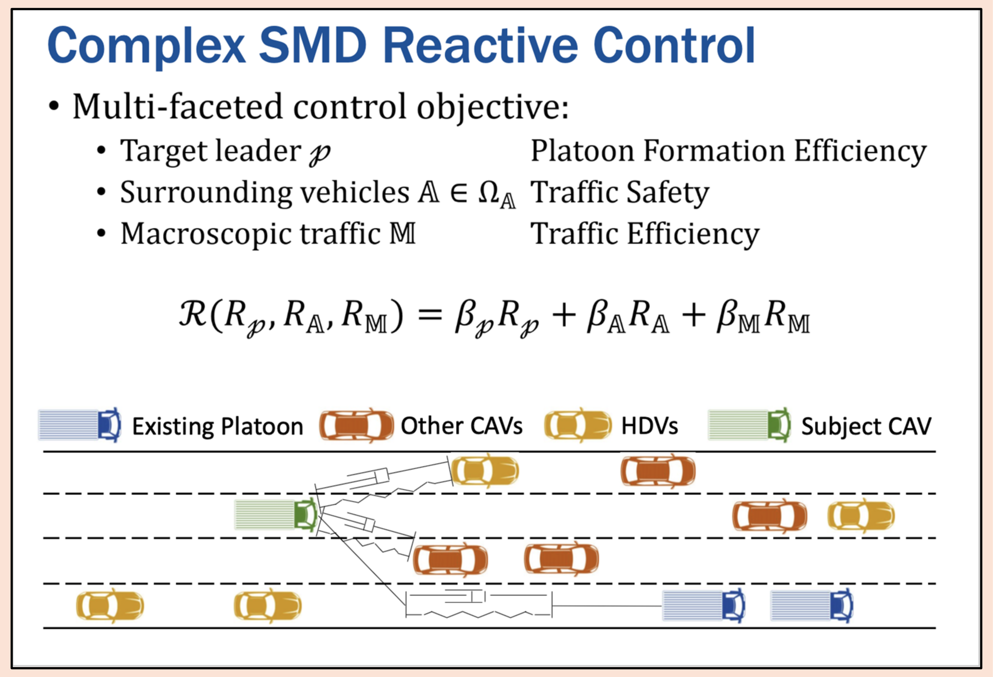
Sequential Truck Platoon Formation (StPF) is a control algorithm that enables Connected and Autonomous Vehicles (CAVs) to form a platoon based on reaction weight parameters (βs). Other studies have explored Machine Learning and Deep Learning approaches to understand the optimal reactions for effective platoon formation. Inspired by these studies, this research develops an experiment where CAV reaction weights for platoon formation are varied across different traffic scenarios. The experiment uses the time taken to form a platoon as a metric to assess how reaction weight parameters affect CAV platoon formation. The results indicate that macroscopic traffic reaction weight is the most crucial factor for successful platoon formation using StPF.

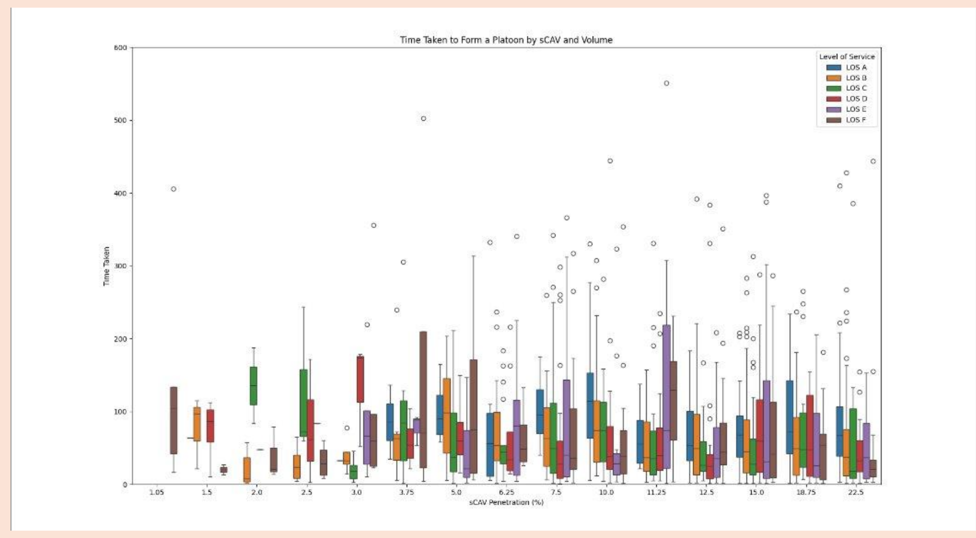
Introduction

Sequential Truck Platoon Formation algorithm, as presented in [1], employs a sophisticated non-linear Spring-Mass-Damper (SMD) controller to facilitate the formation of platoons among Connected and Autonomous Vehicles (CAVs). The SMD controller modulate the behavior of the subject CAV (sCAV) based on various influencing factors. These factors include the dynamics of the target platoon leader (pCAV), adjacent vehicles, and the overarching characteristics of the macroscopic traffic flow. This modulation is achieved through the assignment of specific weights, denoted as β, to each of these influences, thereby guiding the sCAV's response. This research seeks to determine the most effective set of β parameters using time taken to form a platoon as a performance measure.

Experiment

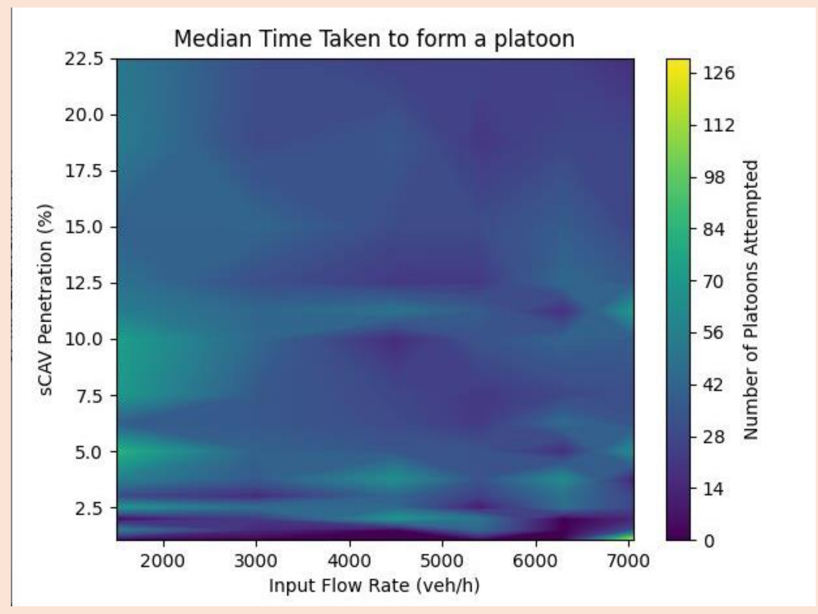
- The experiment employed the advanced traffic microsimulation software SwashSim [2] to replicate the complex dynamics of traffic on multi-lane highways. These virtual highways were designed to include a heterogeneous mix of both CAVs and human-driven vehicles (HDVs).
- The simulations were conducted across a broad spectrum of traffic conditions, categorized using the Levels of Service (LOS) framework. This framework ranges from LOS A, which represents ideal free-flow conditions with minimal traffic interference, to LOS F, which denotes severe congestion and traffic jams. By spanning this entire range, the experiments aimed to capture the varying degrees of traffic density and flow that CAVs might encounter in real-world scenarios.
- In each LOS condition, the experiments systematically adjusted the reaction weight parameters β to analyze their impact on the ability of CAVs to form and maintain platoons.



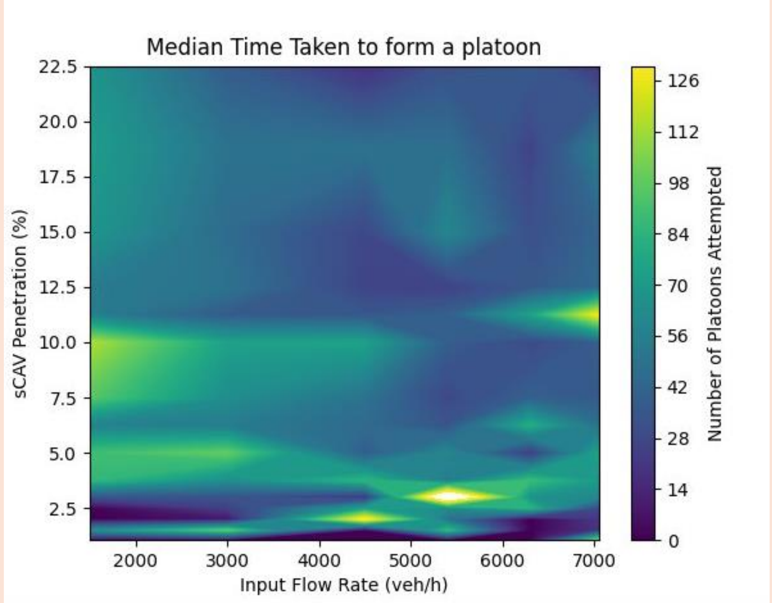


Results

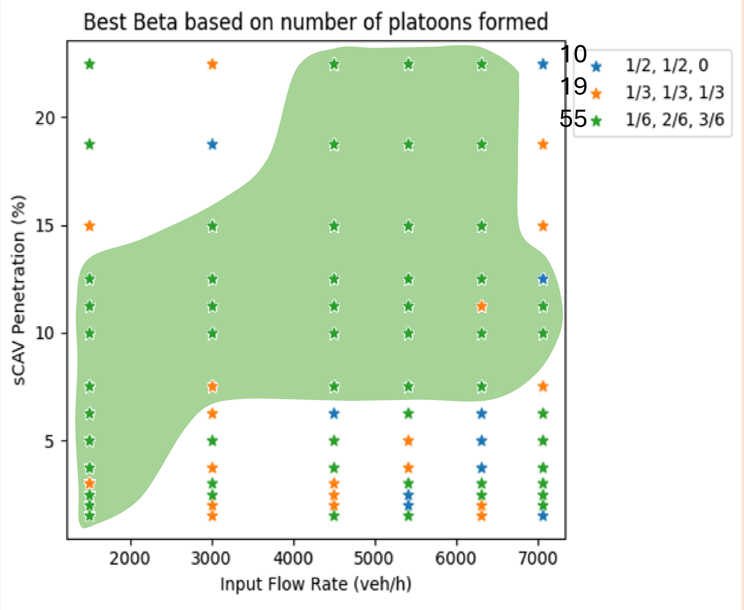
β_1=1/6, β_2=2/6, β_3=3/6

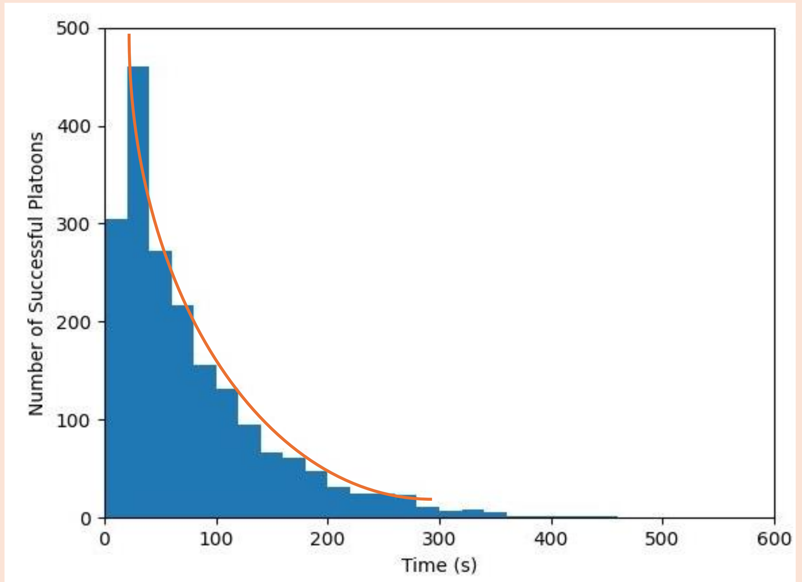


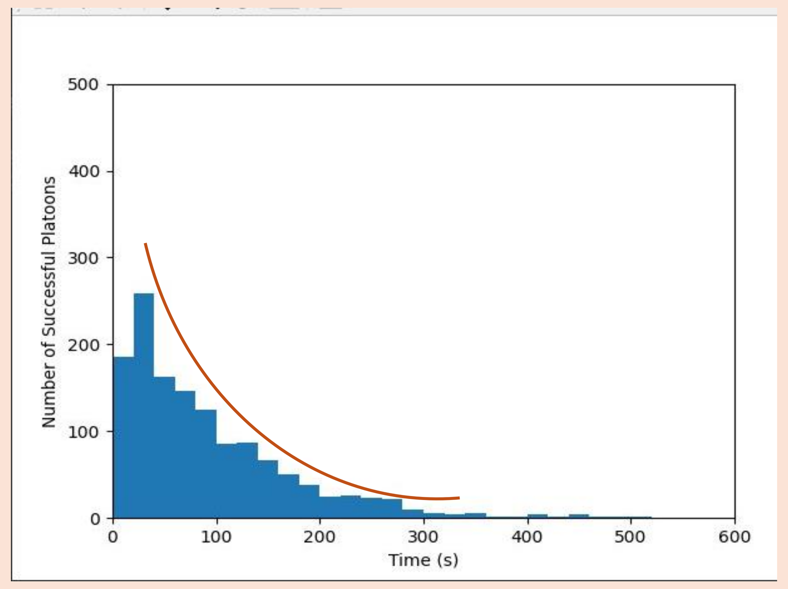
β_1=3/6, β_2=3/6, β_3=0

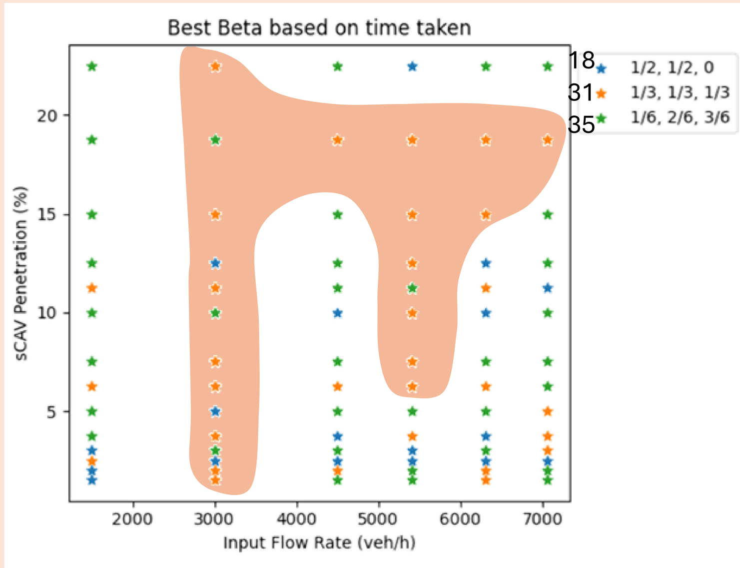


Optimal parameters
For various flow-mix conditions









Conclusion

- Failing to react to macroscopic traffic significantly impedes on platoon formation time.
- A high proportion of CAVs in traffic enhance platoon formation efficiency.
- Stable traffic flow, LOS C-D, coupled with high CAVs presence benefits time taken for platoon formation.
- Number of platoon formation takes a negative exponential distribution.
- Optimal parameter setting is dependent on the traffic condition and the metric.

Future Directions

- Utilizes the Accord.Neuro framework to develop a Neural Network that automates decision-making for CAVs during platoon formation. [3]
- Conduct simulations under various traffic scenarios to validate performance.
- Utilizes simulations result to construct a neural network model within the Accord.Neuro framework.
- Train the neural network model to predict optimal reactions for platoon formation.

References

1. Mukundhan Narasimhan, Lili Du, Scott Washburn. Sequential Truck Platoon Formation in Mixed Traffic using multiple Spring Mass Damper Systems. 2024 American Control Conference, Toronto, ON, Canada, July 10-12, 2024
2. https://github.com/swash17/SwashSim
3. http://accord-framework.net/docs/html/N_Accord_Neuro.htm