Research Report Summary

SAFER-SIM SAFETY RESEARCH USING SIMULATION UNIVERSITY TRANSPORTATION CENTER

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Investigation of Merge Strategies at Ramp Area in Connected Vehicle Environment based on multi-driver simulator system

This study aims to investigate the impacts of merge strategies of a ramp CAV on mainline human drivers.

Previous studies evaluated CAV merge strategies mostly based on either the simulation or the restricted field testing, which lacks consideration of realistic driving behaviors in the merging scenario.

To deal with the research gap, this study developed a multi-driver simulator system and embedded realistic driving behavior in the validation of merge strategies (Figs 1-3). The simulator system designed a data collection module, a vehicle physics module, a scenario management module and a communication module. Particularly, the communication module, it connects multiple driver clients and distributes the simulation data between clients simultaneously.

The study designed a merging scenario as follows (Fig 4): three human-driven vehicles (the 1st ~ 3rd yellow vehicle) are traveling on the mainline, and they form a stable vehicle platoon. A CAV (4th red vehicle) is merging into the mainline from a ramp, and it is supposed to cut in between the 1st and 2nd vehicles in the platoon; the CAV is controlled by the automatic merge strategy.

A set of driving safety and comfort metrics was adopted to verify the merge strategies. In terms of the driving safety, the minimum TTC, the Time Exposed Time-to-collision (TET) and Time Integrated Time-to-collision (TIT) were used. As for the driving comfort, the average jerk, average acceleration, minimum headway distance, the time to minimum distance at the moment when the acceleration

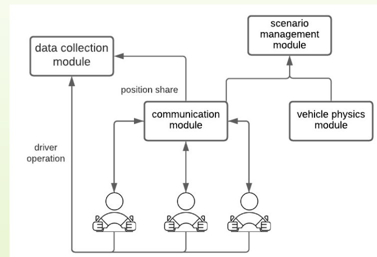

Fig 1. Multi-driver driving simulator system framework

Fig 2. Multiple drivers were simultaneously connected

Fig 3. Scenario screenshot

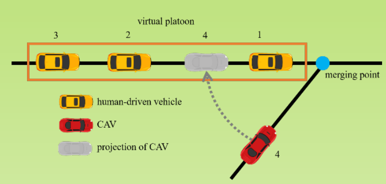

Fig 4. Virtual platoon and ramp

pedal was released (TTMD) and the longitudinal quickness were used.

Four CAV merge strategies were evaluated including the reference-trajectory-based merge strategy and the social-psychology-based merge strategies.

Vehicle	Period	Metrics		Metric Relationship	Best Strategy
2nd car	merging	safety metrics	TET	GFM < KLFE < IDM < AHS	GFM
			minimum TTC	GFM < IDM < KLFE <AHS	AHS
		comfort	mean deceleration	AHS < IDM < KLFE < GFM	AHS
			average jerk during acceleration period	IDM < AHS < KLFE < GFM	IDM*
			minimum headway distance	GFM < IDM < KLFE < AHS	AHS
	following	safety metrics	TET	KLFE < AHS < IDM < GFM	KLFE*
			TIT	GFM < IDM < KLFE < AHS	GFM
		comfort	TTMD	AHS < KLFE < IDM < GFM	GFM
			longitudinal quickness during acceleration	GFM < KLFE < IDM < AHS	GFM
			mean acceleration	AHS < KLFE < IDM < GFM	AHS
			mean deceleration	AHS < IDM < KLFE < GFM	AHS
			average jerk during acceleration period	AHS < IDM < KLFE < GFM	AHS
			minimum headway distance	GFM < IDM < KLFE < AHS	AHS
3rd car	following	safety metrics	minimum TTC	IDM < GFM < KLFE < AHS	AHS
		comfort	minimum headway distance	GFM < IDM < KLFE < AHS	AHS

Note: IDM* and KLFE* had similar performance as AHS. All values were evaluated at 95% significance level.

Outcomes

The results show that these algorithms might not have consistent performance when evaluated by different safety and comfort metrics. In addition, results revealed significant variations of the algorithm influences between the merging and the following periods.

Impacts

The AHS and GFM may have some superiority when evaluated at specific dimensions in terms of driving safety and comfort; nevertheless, the AHS may outperform other merge strategies in more scenarios. Findings suggest that the CAV merge strategy should not only ensure the ramp vehicle's merging task but also consider mainline vehicles' driving performance.

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