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A Study on Road Traffic Flow Enhancement with Optimized ACC Strategies

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While Adaptive Cruise Control (ACC) has become widely adopted, its primary focus remains on the comfort of the individual vehicle's occupants, rather than the optimization of overall traffic flow. Since many traffic jams originate from "shockwaves"—where minute braking actions by individual vehicles are amplified and propagated to those behind them —this study proposes a shift in vehicle control from "individual optimization" to "collective optimization" to prevent the transmission of these disturbances. We propose a new guideline for ACC control that contributes to traffic flow stabilization based on the analysis of real-world traffic data.

First, to understand the actual conditions of urban expressways, we utilized Zen Traffic Data (ZTD) from the Hanshin Expressway to perform a detailed analysis of driver following behavior during saturated rush-hour flow. Under near-critical traffic conditions, we identified consistent statistical trends: Time Headway (THW) follows a gamma distribution and relative velocity (ΔV) follows a Gaussian distribution, both confirmed across multiple road sections (Fig.1).

Based on these findings, we identified key driving indicators, analyzed their transition behavior during acceleration/deceleration (Fig.2), and examined the ideal form of ACC for traffic flow harmonization. The results indicate that managing relative velocity is more effective for "rectifying" traffic flow—stabilizing it and increasing capacity—than merely managing absolute THW values.

This study defines the "approaching state"—where THW is relatively large but Time To Collision (TTC) is decreasing due to relative velocity differences—as the primary target region for control. Since regions with a high ratio of relative velocity to vehicle speed (ΔV/V) are major factors in traffic instability, we hypothesized that a control strategy suppressing transitions into high ΔV/V regions to guide vehicles into a stable following state would be desirable for reducing unnecessary braking (Fig.3). By prioritizing the relative velocity ratio as a primary control indicator, we demonstrated the potential to increase traffic capacity through Vissim simulation-based validation, even with autonomous ACC systems that do not rely on external infrastructure.

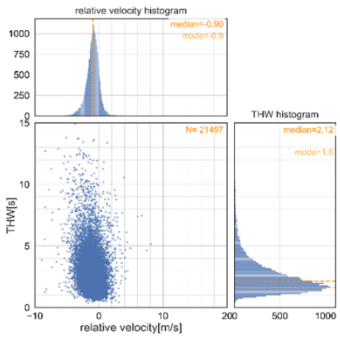

Fig.1 THW and ΔV distribution in start/end of Acc.

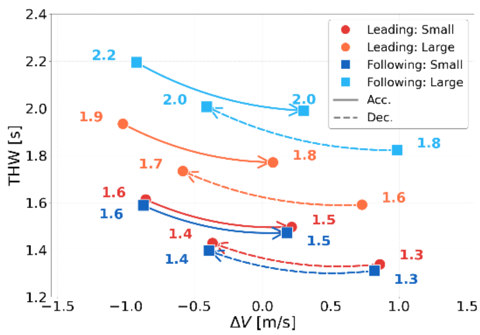

Fig.2 Transition of median THW during Acc./Dec.

Future work must address the assurance of robustness against non-linear behaviors in real-world environments and the development of specific implementation algorithms that consider driver acceptance. Specifically, this includes speed management based on estimated average speeds and the introduction of "damping functions" that allow temporary THW fluctuations to prevent brake propagation. To expand the value and appeal of future vehicles, including connected cars, we aim to establish new design standards for "Social-context-aware ADAS" that account for the impact on the entire traffic stream.

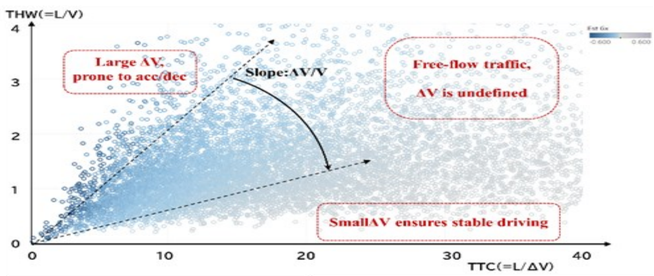

Fig.3 Target Region based on TTC vs. THW