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POLICY BRIEF

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The Missing Link in Automated Vehicle Safety: Projected Braking and Realistic Driving Behavior

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Issue

As more automated vehicles (AVs) gradually appear on our roads, they must be able to safely interact with human drivers as well as existing infrastructure designed with human drivers in mind. Current car-following computer models—which determine how AVs adjust their speed and position relative to other vehicles—often struggle to replicate human driving patterns. This deficiency could lead to unpredictable AV behavior, potentially increasing crash risks, disrupting traffic flow, and creating problems at traffic lights and intersections designed for human drivers. If AVs brake much earlier or later than humans, drivers may be caught in 'dilemma zones' — unable to safely stop or proceed through the intersection.

To address these challenges, we conducted a comprehensive analysis of existing car-following models and developed a novel multi-phase projection-based model that ensures safety while exhibiting human-like driving characteristics. This model is called 'projection-based' because it anticipates future braking scenarios rather than just reacting to current conditions.

Key Research Findings

Standard car-following models have significant limitations in maintaining safe distances between vehicles in everyday driving situations. Our analysis revealed that some current models like Newell's and its extensions can fail to maintain minimum spacing requirements and even result in backward travel (the computer model commands the vehicle to reverse direction, which is clearly unrealistic). Meanwhile, other widely used programs like the Intelligent Driver Model generate unrealistically long braking distances (over 1000m) and can produce backward movement during final stopping phases. The Gipps model stops working in everyday situations like cars stopping at traffic lights or changing lanes. While these academic models aren't directly used in today's AVs, they represent the fundamental approaches that inform how AVs make driving decisions.

Human drivers are able to anticipate when other vehicles may brake, but existing car-following models fail to adequately do this. Our research shows that human drivers continuously anticipate whether the car ahead might suddenly brake and plan their response accordingly. We call this 'projected braking' — essentially looking ahead and preparing for emergency stops before they happen. We created a model that explicitly calculates exactly how both vehicles will move during the entire braking process, from the moment braking begins until both cars come to a complete stop, to ensure safety throughout the entire stopping process, not just at the end. We tested this through mathematical analysis and computer simulations, comparing how existing models handle emergency braking scenarios versus our approach, revealing that current models often react too late or overreact.

Our car-following model mathematically guarantees safety while exhibiting human-like behavior. Our model combines features of an existing model for normal driving conditions with a specialized control law for projected braking scenarios. Unlike previous approaches, our model can be mathematically proven to maintain minimum safe distances and operate within reasonable acceleration/deceleration bounds under realistic initial conditions, offering significant safety improvements over existing models.

The model can be readily installed in AV systems. With only seven parameters (comfort/minimum jam spacings, time gap, reaction time, speed limit, acceleration/deceleration bounds), our model achieves a balance between theoretical rigor and practical implementation. It provides human-like stopping distances (approximately 300m from highway speeds) compared to the excessive 1000m+ distances in some existing models.

Policy Implications

Safety standards should test whether AVs can anticipate and prepare for emergency braking scenarios, not just react to current conditions. Safety certification for AVs should include tests that evaluate the vehicle's ability to maintain safe driving distances not just for current conditions but also for projected emergency scenarios, similar to how humans drive.

LAVs must be compatible with the traffic infrastructure designed for humans. Our model ensures stopping distances comparable to human drivers, helping AVs safely navigate existing infrastructure.

Establishing consistent rules for how AVs behave (such as following distances and braking patterns) could make their actions more predictable to human drivers. The seven core parameters in our model could form the basis for standardized AV behavior profiles, enhancing predictability and safety in mixed traffic situations.

More Information

This policy brief is based on the published articles, "Provably Safe and Human-Like Car-Following Behaviors: Part 1. Analysis of Phases and Dynamics in Standard Models" and "Provably Safe and Human-Like Car-Following Behaviors: Part 2. A Parsimonious Multi-Phase Model with Projected Braking" (UC ITS, 2025) which can be found at https://www.ucits.org/research-project/2022-39/. For questions, please contact Wen-Long Jin at wjin@uci.edu.

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