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Testing Autonomous Driving Control Algorithms with Scaled Vehicles

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The validation of Connected and Automated Vehicle (CAV) functions still faces a significant gap between purely virtual simulations and expensive full-scale experimental campaigns. This work presents a mixed-reality scaled-vehicle testbed designed to support the development, verification, and validation of autonomous driving control algorithms within a controlled and repeatable indoor environment. The proposed platform employs 1:18 scale vehicles operating inside a 6×5 m^2 arena equipped with a ceiling-mounted vision system for high-frequency localization and a real-time communication and control architecture based on Wi-Fi and CAN protocols.The framework enables rapid prototyping through MATLAB/Simulink automatic code generation and deterministic execution on a real-time target machine, thus preserving consistency with industrial automotive workflows. To enhance realism while ensuring operational safety, the physical environment is synchronized with a digital twin in which virtual agents, such as pedestrians and surrounding vehicles, interact with real scaled vehicles in closed-loop scenarios. This hybrid approach allows the reproduction of complex and safety-critical maneuvers under repeatable conditions. The proposed infrastructure is integrated within a V-cycle methodology for autonomous driving system validation, covering early-stage simulation, hardware-in-the-loop testing with scaled vehicles, and progressive transfer toward full-scale implementation. Experimental results demonstrate the capability of the platform to reproduce collision-avoidance and overtaking maneuvers involving dynamic obstacles, while monitoring vehicle trajectories, accelerations, and control actions in real time. The testbed also serves as a living laboratory for public dissemination activities on automated driving technologies. Overall, the developed framework represents a cost-effective and scalable solution for bridging the gap between simulation-based development and full-scale vehicle testing in autonomous driving research.

Primary author: TRAMACERE, eugenio (Politecnico di torino)

Co-authors: TONOLI, Andrea (Politecnico di Torino); CASTELLANOS MOLINA, Luis Miguel (Politecnico di Torino)

Presenters: CASTELLANOS MOLINA, Luis Miguel (Politecnico di Torino); TRAMACERE, eugenio (Politecnico di torino)

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