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Accelerating Sophisticated Automated Driving System Development and Evaluation through Proactive Multi-Agent Traffic Simulation

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This study proposes a novel virtual testing platform designed to accelerate the development and evaluation of Automated Driving Systems (ADS) through proactive multi-agent traffic simulation. Conventional field operational tests are limited in their ability to capture rare, complex, and safety-critical scenarios, which are essential for improving ADS performance. To address this limitation, the proposed platform enables systematic generation of challenging traffic situations that are aligned with the intended capabilities and performance requirements of ADS.

The platform integrates multi-agent traffic simulation with ADS, allowing continuous interaction between the ADS and surrounding traffic participants. The platform is characterized by four key features (Fig. 1). First, iterative simulations facilitate continuous improvement of recognition and path-planning algorithms. Second, realistic behavioral models of diverse traffic participants expand the range and fidelity of test scenarios. Third, scenario difficulty is dynamically adjusted based on prior assessments of ADS performance. Fourth, the refinement of simulation conditions is guided by the sophistication level of the ADS, enabling progressive evaluation.

To support the development of advanced ADS, this study introduces a conceptual framework for driving proficiency defined by three key dimensions: safety, smoothness, and resilience. Safety refers to the ability to avoid accidents and unsafe maneuvers, smoothness represents the ability to maintain efficient and non-disruptive traffic flow, and resilience denotes the ability to flexibly cope with complex and unpredictable traffic situations. Addressing the so-called “long-tail problem” requires focusing not only on rare events but also on frequently occurring complex interactions that challenge these aspects of driving performance. A representative application scenario considered in this study is the interaction with emergency vehicles in dense urban traffic environments (Fig. 2). In such situations, ADS must comply with traffic regulations while also responding appropriately to implicit expectations from surrounding drivers. This study defines behavioral requirements for handling approaching emergency vehicles based on both legal constraints and observed human driving practices. The proposed platform reproduces such scenarios by incorporating both emergency vehicle driver models and surrounding vehicle behavior models that respond to the presence of emergency vehicles.

As sensing and artificial intelligence technologies continue to advance, ADS are expected to achieve higher levels of performance in increasingly complex environments. The proposed virtual testing platform provides a scalable and systematic approach for evaluating ADS under such conditions. By enabling efficient generation and assessment of challenging scenarios, the platform contributes to accelerating ADS development, improving safety validation, and ensuring adaptability to diverse real-world traffic situations.

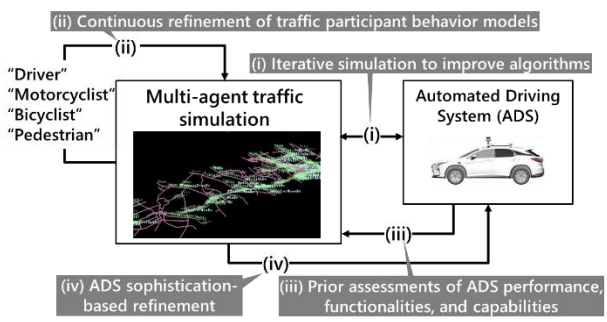

Fig. 1 Conceptual framework of the proposed virtual test platform based on the interaction between multi-agent traffic simulation and automated driving system (ADS)

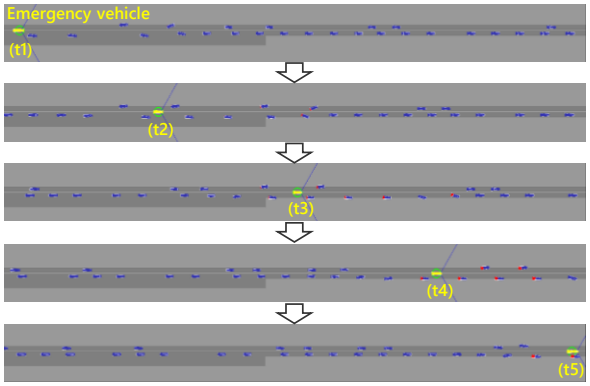

Fig. 2 Simulation of an emergency vehicle passage through a congested highway.