

Development of a Photorealistic Simulation Platform for Model-Based Development of End-to-End Autonomous Driving

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KEYWORDS: Software and Its Elemental Technologies, Automated Driving System, Simulation, End-to-End Autonomous Driving, 3D Gaussian Splatting, Photorealistic Rendering

Background and Objective—E2E autonomous-driving models infer trajectories from camera images and vehicle states; therefore, evaluating their interaction with vehicle motion before on-road testing is essential. Recorded-image tests are generally open loop and cannot reflect predicted trajectories in subsequent vehicle behavior. This study develops a photorealistic MBD platform that integrates vehicle simulation, 3D Gaussian Splatting (3DGS), and an E2E trajectory predictor within a unified evaluation environment.

Platform Design—A nuScenes scene [1] was reconstructed using RoadRunner and Unreal Engine for CG and OmniRe [2] for time-dependent 3DGS rendering. A MATLAB three-degree-of-freedom vehicle model generated motion states and synchronized both renderers through Python. As shown in Fig. 1, object positions and motion were synchronized between the CG environment and 3DGS. VAD [3] ran separately and exchanged rendered images, vehicle states, and predicted trajectories with MATLAB via ROS 2 [4], forming an integrated environment–vehicle–AI evaluation chain.

Evaluation and Results—On a workstation with 64 GB RAM and an NVIDIA GeForce RTX 3090 Ti, CG-only, 3DGS-only, and combined rendering achieved 12.60, 9.57, and 7.52 steps/s, respectively, while object motion remained synchronized. ROS 2 data exchange of rendered images, vehicle states, and predicted trajectories was verified. As shown in Fig. 2, VAD generated three candidate paths that were compared with the ground-truth trajectory. These results confirm that the environment model, vehicle model, rendering system, and E2E model can operate in a synchronized workflow as an integrated MBD evaluation chain.

Discussion—The verified synchronization and data exchange interfaces demonstrate the technical feasibility of the platform as an MBD environment for examining photorealistic sensor inputs, vehicle dynamics, and E2E outputs before on-road testing. The current setup remains open loop because vehicle states follow the ground-truth trajectory; closed-loop integration is the next step toward evaluating stability, error propagation, and vehicle-control performance. Further work should also address VAD's dependence on predefined navigation commands and 3DGS artifacts at unseen viewpoints.

Conclusion—The proposed platform synchronizes CG, 3DGS, vehicle states, and VAD through ROS 2 and enables their outputs to be handled within a single evaluation workflow. The successful connectivity, synchronized rendering, and trajectory exchange establish the platform's basic feasibility as an MBD environment for the development and evaluation of E2E autonomous driving before on-road testing. Future work will close the simulation loop and evaluate closed-loop vehicle-control performance in diverse scenarios.

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Fig. 1 Synchronized rendering results of the CG environment and 3DGS



Fig. 2 Comparison between VAD-predicted paths and the ground-truth trajectory