Make it Real – Digital Reconstruction of Trondheim

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New computer vision techniques can now create high-fidelity urban digital twins, using data collected at your doorstep.

INTRODUCTION

Major Norwegian cities such as Ålesund are utilizing smart technologies for urban development and planning (Almaas, no date). Digital twins (DTs) can play an important role in improving the sustainability of urban environments (LDTRC, 2022; Stone, 20. They can assist in modeling traffic dynamics, allow stakeholders to preview construction plans within a realistic 3D environment, or improve simulators in disciplines like autonomous driving (AD) research with closed feedback loops. Traditionally, creating virtual three-dimensional representations of cities involves the use of expensive specialized equipment or labor-intensive manual modeling. Recent advances in neural scene representations for novel view synthesis (NVS), like 3D Gaussian Splatting (3DGS), offer efficient, photorealistic 3D reconstruction using only recorded data like video, location, etc. (Kerbl et al., 2023). Such data-driven methods promise affordable systems for real time interaction and scene manipulation, providing more municipalities, urban developers, and researchers of various fields with powerful tools for planning, model evaluation and informed decision making.

METHOD

Our mission at the Computer Vision Lab at IDI, NTNU, is to create and analyze a system for multi-purpose 3D reconstruction of target regions within the larger Trondheim area, using 3DGS-based NVS methods.

The backbone of the project is the CARLA simulator (Dosovitskiy et al, 2017), a popular tool for AD research. It can already simulate urban environments at the road network level and even has some limited DT functionality of its own. Instead of using CARLA's native, Unreal-based rendering pipeline, we rely on Novel View Synthesis (NVS) to generate accurate, photorealistic images.

Figure 1: A camera image vs CARLA's procedurally generated digital twin (Hagberg, 2025).

3D Gaussian Splatting (3DGS) is a powerful machine learning technology that allows the digital reconstruction of the physical world. Using recorded location, image, and depth information, it can learn to synthesize new images from positions which no camera has ever recorded – so-called *novel views* (Kerbl *et al.*, 2023).

Figure 2: How the proof-of-concept simulation pipeline works. Raw data is first collected in a designated area using the sensors of the lab's research vehicle (top). The preprocessed data is then used to train the 3DGS system. Map data for this area is sourced from the public OpenStreetMap (OSM) project and Kartverket (center). The resulting pipeline (bottom) generates a georeferenced, photorealistic representation of the recorded environment that integrates seamlessly with the CARLA simulator: A virtual camera (e.g., mounted on a virtual vehicle) can be placed anywhere on the area map in CARLA and query the 3DGS system on what it would see if it were physically there.

RESULT

The usefulness of this pipeline hinges on the quality of the generated images. An in-depth analysis of the pipeline demonstrates their high quality: Using real-world data recorded in Trondheim, it achieves a *Peak Signal-to-Noise Ratio* (PSNR) of 28.20, a *Learned Perceptual Image Patch Similarity* (LPIPS) of 0.22 and a *Structural Similarity Index Measure* (SSIM) of 0.91.

These metrics ensure visual quality and realism, critical for urban planning and autonomous driving simulations, all without manual manipulation of the data.

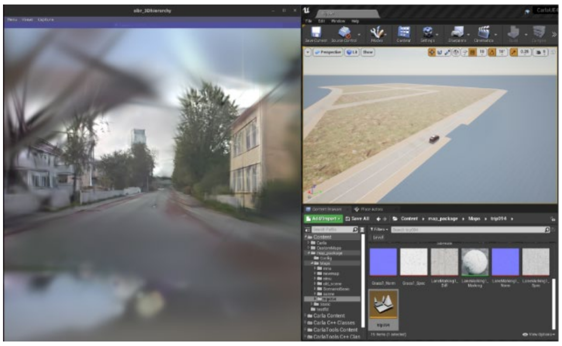

Figure 3: Example scenario (Hagberg, 2025): A virtual agent traverses a virtual copy of Klæbuveien inside CARLA (right). The 3DGS system, Hierarchical 3D Gaussians (Kerbl et al., 2024) receives the position and heading of the virtual vehicle's front camera as it drives and renders the novel view (left). The result is a real-time simulation of the agent's view, driving on a local road.

CONCLUSION

The project revealed significant engineering challenges with integrating NVS solutions into existing simulators, ranging from coordinate system conversion to image preprocessing. This currently results in unwieldy and manual data processing pipelines that are still far from full automation. That said, it is already significantly less manual labor than handcrafting the virtual environment manually. Furthermore, the field is evolving rapidly, allowing for a higher level of automation in the near future. As of September 2025, the latest CARLA version has native support for neural rendering through NVIDIA's NuRec (CARLA, 2025), which could significantly accelerate the development process.

Neural rendering pipelines represent a foundation for supporting multiple downstream tasks that require virtual, high-fidelity camera data. Integrating CARLA as an AD-focused research tool allows for the photorealistic simulation of agent-environment interactions in existing places. Beyond AD research, CARLA has already been extended to various urban applications, including co-simulation with traffic microsimulators like SUMO and AIMSUN for traffic research (CARLA, no date; Aimsun, 2024).

By nature of its CARLA and Unreal foundations, future visions of our pipeline include the ability to manipulate the environment, be it dynamic objects like other traffic participants, or static ones like buildings, roundabouts, or other urban infrastructure.

For Norway, this means cities may soon be able to visualize and test new infrastructure, buildings, and traffic scenarios with greater realism and speed. The integration of 3DGS scenes with simulators and architectural models is crucial for bridging the gap between digital planning and real-world outcomes.

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