Professorship of Autonomous Vehicle Systems
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*MA*

# Diffusion-based safety-critical scenario generation

This thesis explores diffusion-based methods to generate and transform safety-critical driving scenarios, bridging the gap between simulation, real-world data, and perception-level validation.

## Background

Safety-critical scenario generation is essential for the validation of autonomous driving and ADAS systems. While real-world datasets such as nuScenes capture valuable long-tail events, they remain limited in terms of coverage, diversity, and controllability. Conversely, traditional simulation approaches provide flexibility but often lack photorealism, reducing their effectiveness for perception-driven evaluation.

Recent advances in diffusion models offer a promising solution by enabling controllable, high-fidelity generation and editing of complex scenes. By conditioning these models on semantic, geometric, or risk-related constraints, it becomes possible to systematically create realistic and diverse safety-critical scenarios.

This thesis aims to develop an end-to-end pipeline for generating such scenarios using diffusion models, with a focus on both editing real-world data and synthesizing photorealistic sensor outputs for robust perception-level validation.

## Language

English

## Your Role

- **Model Development & Research:** Investigate diffusion-based methods for scenario generation and editing, and identify suitable conditioning strategies (semantic, geometric, risk-aware)
- **Implementation & Evaluation:** Build a pipeline for editing real-world datasets and synthesizing photorealistic scenarios, and evaluate results in terms of realism, diversity, and safety relevance

## Was should you bring along?

- Strong interest in generative models and autonomous driving
- Hands-on motivation for deep learning and simulation-based validation
- Programming skills (Python, PyTorch)
- Basic knowledge of computer vision / machine learning
- Independent and structured working style

Work can begin immediately. If you are interested in this topic, please first have a look at our recent survey paper: https://ieeexplore.ieee.org/document/11370877

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