Institute of Automotive Technology
TUM School of Engineering and Design
Technical University of Munich

Bachelor Thesis / IDP / Guided Research

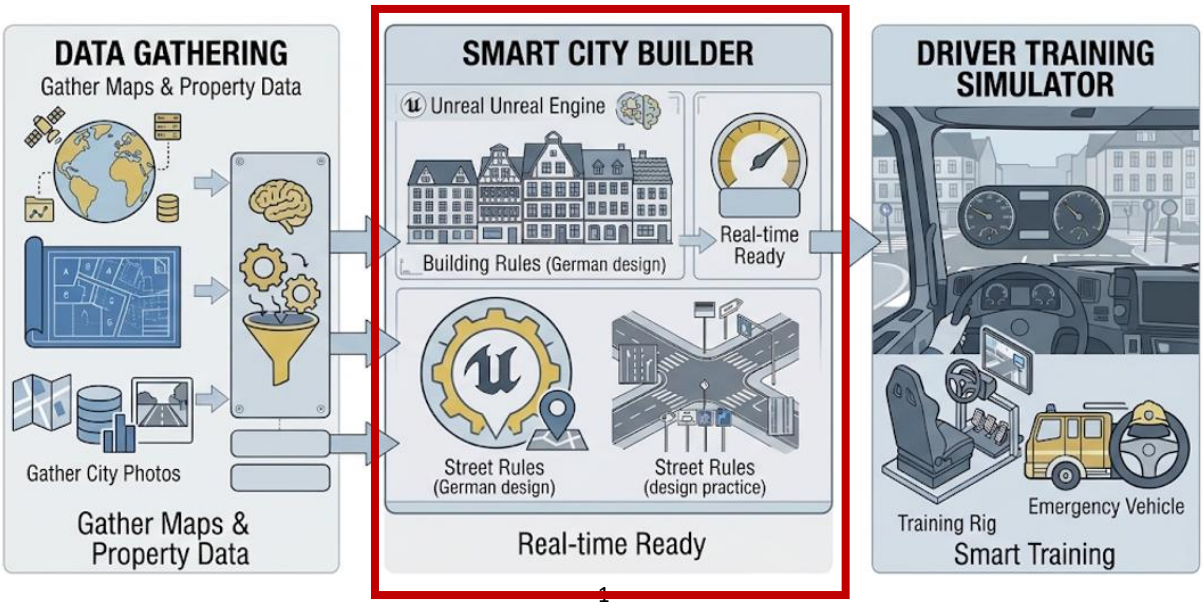
Procedural Generation of Region-Specific Urban Environments for a Real-Time Driving Simulator in Unreal Engine

As part of the research project EfaSim (KMU-innovativ: Forschung für die zivile Sicherheit), the Institute of Automotive Technology together with an industry partner is developing a digital training platform for emergency response driving. A microscopic traffic simulation is coupled bidirectionally with a real-time visualisation in Unreal Engine so that volunteer fire brigades and THW units can train emergency runs in realistic virtual road environments. The coupling and the vehicle simulation are already in place.

What is missing is the environment these emergency runs take place in. The training value depends on the trainee recognising the situation: a narrow residential street lined with parked cars, a signalised intersection with restricted visibility, a pedestrian crossing in front of a school. The road space and its surroundings therefore have to correspond to what crews actually encounter in German cities. Modelling entire districts by hand is not feasible at that scale, so the environment has to be generated. A rough generation outline based on Unreal Engine's PCG framework exists, but it is neither region-specific nor complete: buildings and roofs are generated crudely, and the street space — crossings, markings, signage, green strips, street furniture — is largely absent.

This thesis develops a procedural content generation pipeline in Unreal Engine that reconstructs region-specific German urban environments from open cartographic data. The emphasis is on the generation of the street space and its environment (70 %) and on the refinement of the existing building and roof generation (30 %); façade and façade-element assets are provided. The existing outline may be refined or replaced entirely by an approach of the candidate's own.

The generation is driven by open data such as OpenStreetMap or Mapillary, which is incomplete and inconsistent in exactly those attributes that matter here, so the pipeline has to fall back on rule-based defaults derived from German road design and signage practice wherever the data is silent — without generating an environment that contradicts the real location. At the same time the result has to remain a driving simulator: the scene must render with a large number of simultaneous actors at no less than 30 fps, with 45 fps or more as the target, so the asset, instancing and level-of-detail budget is an input to the design of the generation rather than something optimised afterwards.



Work Packages

- Literature and tool review on procedural content generation for urban environments, on the PCG framework in Unreal Engine 5, and on the automated reconstruction of cities from open geodata
- Analysis of the existing generation outline: quality of the current building and roof generation, missing elements of the street space, and identification of the features that make German urban environments recognisable
- Data pipeline: acquisition, filtering and interpretation of open cartographic data (road classes, lane counts, building footprints, heights and roof shapes, land use) and derivation of a generation-ready intermediate representation
- Refinement of the building generation from the provided assets: storey subdivision and façade-element placement, opening rhythm, and data-driven selection of roof form and roof detail
- Generation of the street space: carriageway and lane layout, sidewalks and kerbs, pedestrian crossings, road markings, traffic signs and signal heads, following German design and signage rules wherever the data provides no attribute
- Generation of the surrounding environment: green strips and street trees, parked vehicles, street furniture and land-use-dependent surroundings, with rule-based plausibility for incomplete data
- Real-time capability: asset, instancing and level-of-detail concept, and runtime evaluation of frame rate and memory footprint against the target of 45+ fps with multiple simultaneous actors
- Validation on at least one reference district in Germany: comparison of the generated environment against aerial and street-level imagery, and assessment of the achievable degree of automation

Prerequisites

- Experience with game engines, from coursework or personal projects
- Knowledge of game development workflows
- Basic programming skills in C++
- Basic experience with 3D software (e.g. Blender)
- Experience with Unreal Engine 5 (current version 5.7), in particular its PCG framework, is an advantage
- Knowledge of game asset optimisation is an advantage
- Independent and structured working style

The generation has to be based on OpenStreetMap or comparable open cartographic data, and the toolchain used has to be open source.

Variations of the topic and additional research questions proposed on your own initiative are always welcome. If interested, please send your CV, transcript, and a short motivation.

The write-up should document the work steps clearly. The candidate commits to working independently and citing all resources used properly.

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Issued: 19.08.2026	Due: 4 – 6 Months