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

Master-Thesis

Plausible Motion Synthesis for Traffic-Simulation-Driven Vehicles in a Real-Time Unreal Engine Environment

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 itself is already in place.

What is missing is credible motion of the surrounding traffic. The traffic simulation is authoritative for traffic logic — car following, right of way, signal control — but it describes each vehicle as a point on a lane, updated in discrete steps, with a heading taken from the polygonal lane geometry. Applied directly to actors in the visualisation, these states produce visibly artificial motion: vehicles rotate abruptly at junctions, jump sideways when changing lane, travel without any body roll or pitch, and their wheels do not correspond to their movement.

This thesis develops a motion synthesis layer between the traffic simulation and the visualisation. It turns the discrete, lane-based state stream into continuous and plausible vehicle motion at rendering frame rate, without taking authority away from the traffic simulation, and within a computational budget that still allows a large number of simultaneous agents.

Two constraints make this more than a smoothing exercise. Any smoothing introduces a deviation from the state that the traffic simulation considers true, so the layer has to bound that deviation such that gaps, right of way and lane occupancy remain visually correct — in a training environment a trainee must never see a vehicle that contradicts the underlying traffic logic. At the same time, full rigid-body physics is not an option for hundreds of agents, so the plausibility has to come from a kinematic and procedural description rather than from a solver.

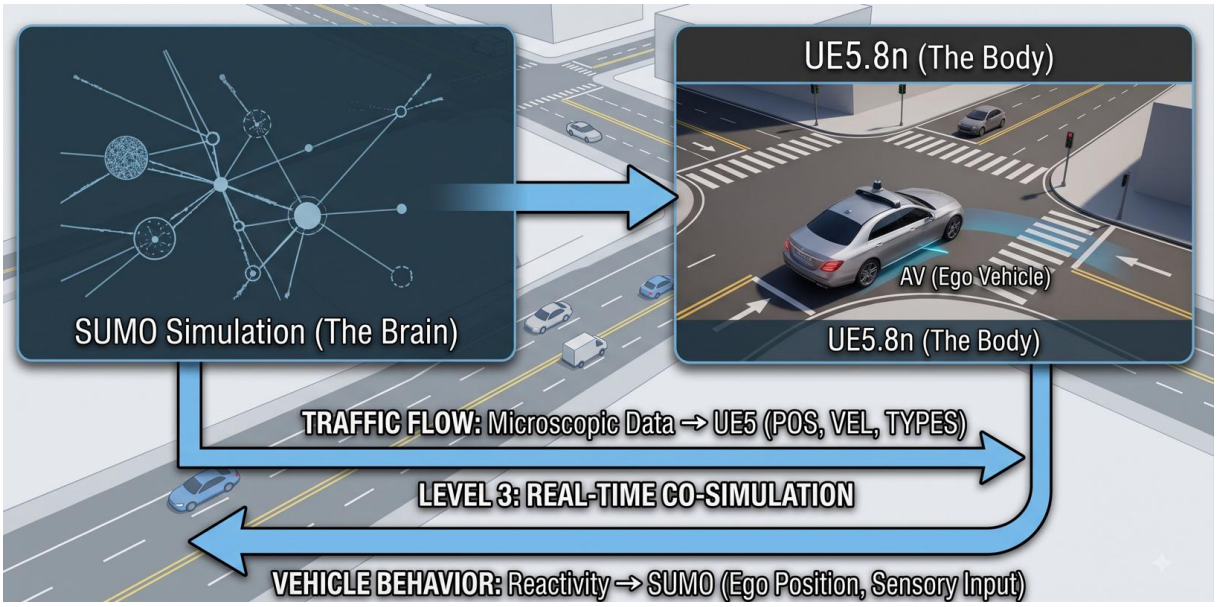

Figure 1: General workflow.

Work Packages

- Literature review on motion synthesis and trajectory smoothing for simulated traffic, on curvature-continuous path representations (e.g. clothoids, splines) and on kinematic vehicle models
- Quantification of the artefacts of the existing coupling: heading discontinuities at junctions, lateral jumps during lane changes, and the influence of the update rate on the perceived motion
- Design of the motion synthesis layer: curvature-continuous path generation from the lane geometry, temporal interpolation and dead reckoning between simulation steps, latency compensation
- Derivation of vehicle-consistent motion from the smoothed path: heading and steer angle from path curvature, wheel rotation from travelled distance, lateral offset blending for lane changes
- Procedural secondary body motion from the resulting accelerations: roll, pitch and suspension travel through spring-damper filters, parameterised per vehicle class
- Definition and enforcement of deviation bounds so that gaps, right of way and lane occupancy from the traffic simulation remain preserved
- Level-of-detail concept and performance evaluation: cost per agent and number of simultaneous agents at the target frame rate, from actor-based representation near the camera to instanced representation at distance
- Validation against reference trajectories and subjective assessment of the perceived realism with users

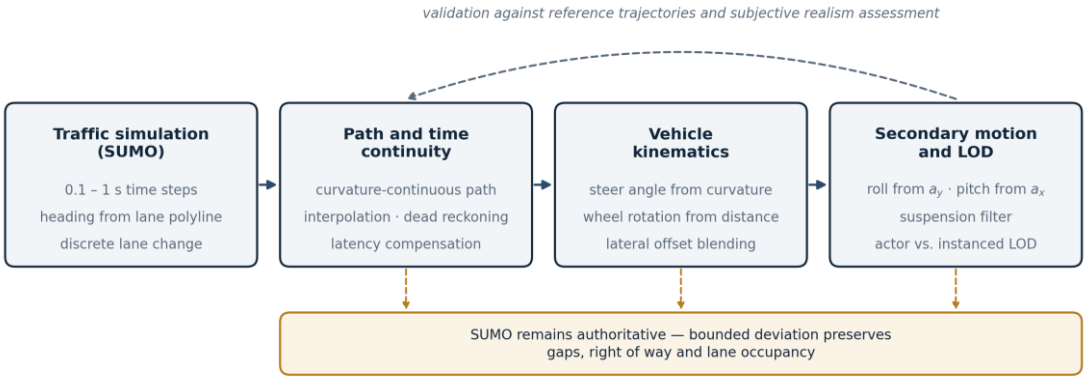

Figure 2: Suggested schema

Prerequisites

- Programming skills in C++ and experience with, or strong interest in, Unreal Engine
- Basic knowledge of vehicle kinematics and of interpolation or spline methods
- Interest in real-time systems and performance optimisation
- Python for the traffic simulation side (TraCI) is an advantage
- Independent and structured working style

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.

Prof. Dr.-Ing. M. Lienkamp

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Due: 6 Months