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

Bachelor-Thesis

Measurement-Based Modelling and Characterisation of Emergency Vehicles for Real-Time Traffic Simulation

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 perceived realism of such a platform depends not only on the surrounding traffic but on the behaviour of the emergency vehicle itself. Fire service vehicles differ fundamentally from passenger cars in mass, centre of gravity height and response delay — properties that determine how a driver can take a corner under time pressure. So far, these vehicles are represented in the simulation by generic vehicle dynamics.

This thesis closes that gap. The real driving behaviour of fire service vehicles is recorded in a dedicated driving test, a simplified and real-time capable model is identified from the measurement data, and the identified parameters are applied on both sides of the simulation: as a physics-based ego vehicle in Unreal Engine (Chaos Vehicle) and as a parameterised vehicle type in the microscopic traffic simulation, connected through the real-time communication interface.

Two aspects make this more than a parameter-fitting exercise. A fire service vehicle is roll-limited rather than grip-limited, so its handling limit follows from centre of gravity height and roll stiffness instead of tyre friction, and a partially filled water tank is dynamically a different vehicle from a full or an empty one. Furthermore, an inertial measurement unit alone cannot separate road bank angle from lateral acceleration — a limitation that must be resolved through the measurement setup rather than through filtering.

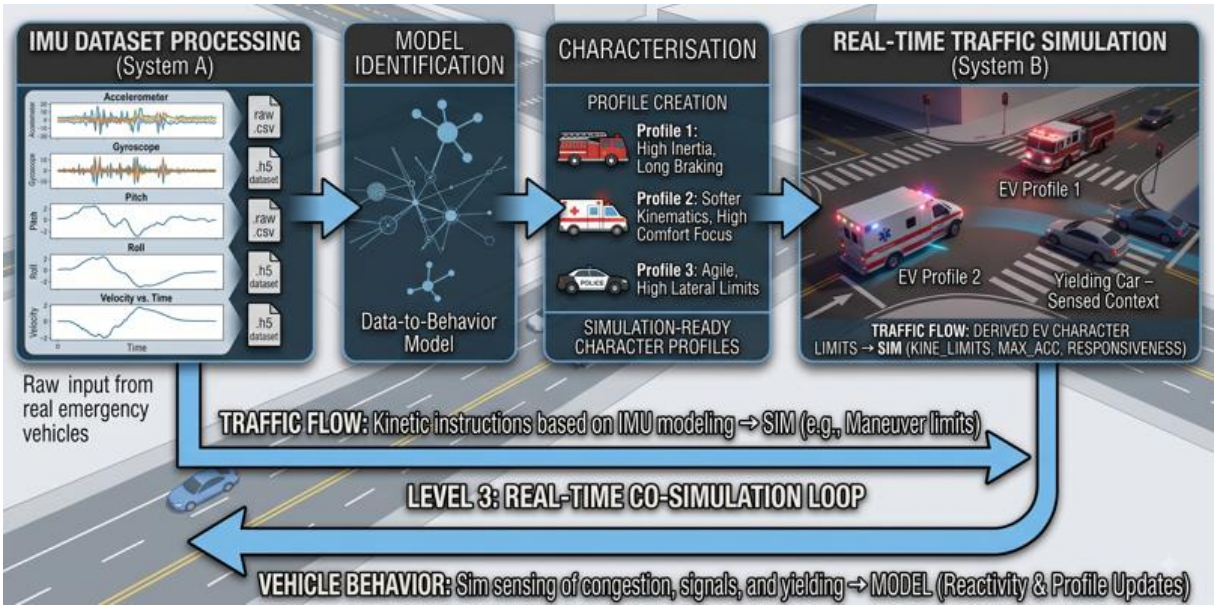

Figure 1:General workflow..

Work Packages

- Literature review on the driving dynamics of heavy and emergency vehicles and on simplified, real-time capable vehicle and roll models

- Analysis of the possibilities and limits of representing emergency vehicle dynamics in Unreal Engine (Chaos Vehicle) and in the microscopic traffic simulation, including the coupling of both
- Detailing of the measurement programme described above and setup of the measurement chain: 6-axis IMU, GNSS, steering angle signal, external video and their time synchronisation
- Execution of the driving test with fire service vehicles in cooperation with the fire brigades of the district of Pfaffenhofen/Regensburg, in full and empty tank configuration
- Signal processing and parameter identification: sensor alignment, lever-arm correction, sensor fusion and derivation of the longitudinal, vertical, roll, pitch and yaw characteristics
- Parameterisation of the Chaos Vehicle model (centre of gravity height, roll and cornering stiffness, drivetrain) and of the corresponding vehicle type in the traffic simulation
- Extension of the communication interface by the vehicle states required for the visualisation and validation of the model by open-loop replay of the measured driver inputs
- Documentation and provision of the recorded dataset for further use within the project consortium

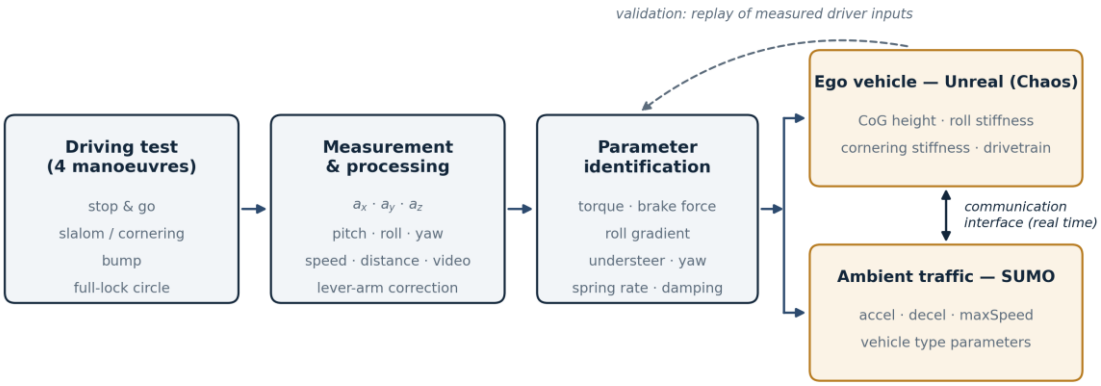

Figure 2: Suggested schema.

Prerequisites

- Programming skills in Python (experience with C++ or Unreal Engine is a plus).
- Basic knowledge of vehicle dynamics and measurement technology.
- Willingness to take part in on-site driving tests together with the fire brigades.
- German/English language.
- 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	Supervisor: Cristian Cubides-Herrera, M.Sc.
Issued: 11.08.2026	Due: 4 Months