Christian-Albrechts-Universität zu Kiel
Technische Fakultät

Modular Sensor-testing Framework for Autonomous Rail Vehicles

Proposal Presentation Bachelor Theses

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Why Simulation-Based Testing?

- Autonomous rail vehicles rely on perception accuracy for safety.
- Real-world testing is expensive, risky, and non-reproducible.
- Simulation enables early, safe testing of perception and control.
- My thesis: develop a modular, reproducible simulation framework to support such testing in terms of Sensors in train Vehicles.

What Problem Am I Solving?

- Research needs a flexible tool to test different sensor configurations under controlled conditions.
- This thesis will focus on designing the **core simulation infrastructure**, not full system complexity.
- Connection to **DataTrain project:** providing a reusable testing foundation.

Research Focus

“How can a modular simulation framework be structured to enable reproducible testing and comparison of virtual sensor configurations for autonomous rail vehicles?”

Objectives:

- Design a simple but extensible simulation setup.
- Allow testing of multiple sensor types and conditions.
- Provide standardised data outputs for analysis.
- Enable future extensions within the DataTrain project.

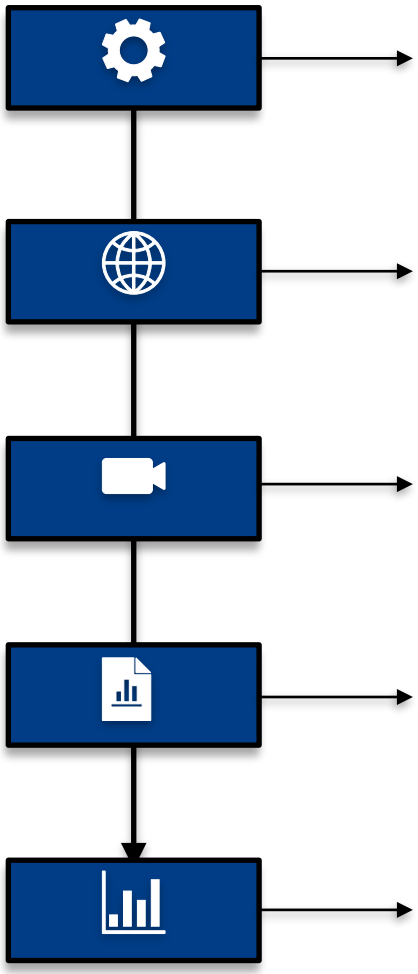
Core Deliverabels (Hard Goals)

Goal	Rational	Measurable Outcome
Basic Simulation Environment	Foundational testbed	2 environments × 2 obstacles × 2 sensors
Modular Architecture	Easy extension	Configurable parameters, simple manual
Standardized Data Interfaces	Comparability	Detectable, exportable sensor results

Optional Extensions (Soft Goals)

- Additional sensors or complex scenes
- YAML-based configuration interface
- Extended evaluation & visualisation of Results
- Debugging tools for sensors
- Containerised deployment in Docker
- Basic actuation simulation (PID) for improved Train behvior

System Overview



Configuration Interface:
defines scenario parameters (environment, sensor setup, obstacles).

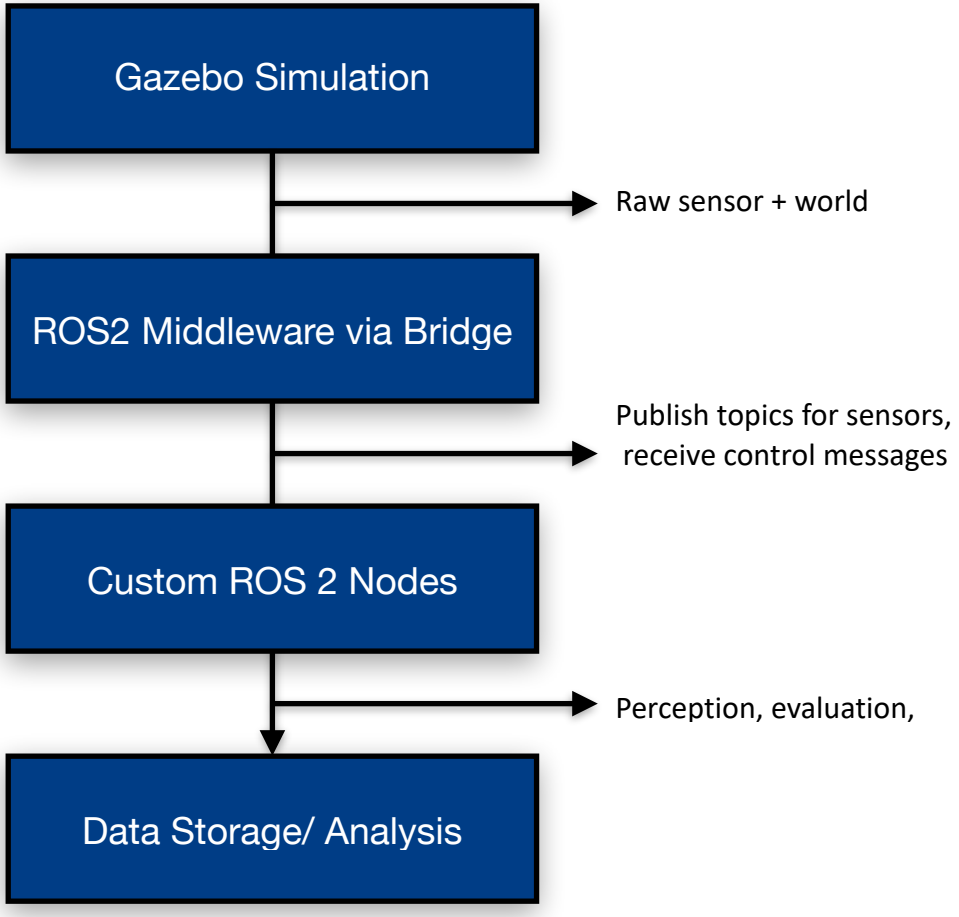
Simulation Core:
Generates the environment and train behaviour according to config.

Sensor Modules:
Collect simulated data (camera, LiDAR, etc.) from the simulation.

Data Interface:
Standardises and records outputs in a consistent format.

Evaluation/ Visualisation:
Interprets results, visualises detections, and validates performance.

How is the Framework Built?



- Independent modules communicate through defined interfaces.
- Emphasis on simplicity and traceability.
- The structure supports plug-and-play sensor integration and reproducible testing.

Implementation Timeline:

- November: Setup Deployment and Create base Simulation
- Dezember Sensor Framework Integration
- Januar: Implement Data Interface and Logging Design, Prepare Analysis and Evalutaion (A &E)
- February: Finish Analysis and Evaluation, Implement optional Debugging und Visializaion Tools. Finalise Integration and Documentation
- March: Theses end and Submission

Writing Deadlines:

- 16.01.2026: Submission of first draft chapters Introduction, Related Work, and Deployment Setup.
- 09.02.2026:Submission of draft for System Design and start of implementation documentation.
- 02.03.2026:Submission of draft chapters —Evaluation and Results.
- 15.03.2026 (latest): Submission of the final complete thesis draft

Deliverables & Impact

- Functional modular simulation framework
- Configurable test scenarios with reproducible results
- Documented interfaces and example configurations
- Foundation for future DataTrain extensions

“A minimal but extensible platform for safe, reproducible virtual sensor testing.”

Conclusion

- The project focuses on clarity, modularity, and reproducibility.
- Establishes groundwork for future sensor integration and evaluation tools.
- Next step: feedback and approval of the proposal to proceed with implementation.

“Thank you for your attention — I’m happy to discuss questions or feedback.”