SAFEXPLAIN Final Demo – Railway Case Study

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Consortium partners: NavInfo Europe, BSC, Ikerlan, AIKO, RISE, Exida

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Introduction and Purpose

From Automated to Autonomous Railways

Autonomous trains are expanding fast, but high-speed and regional networks remain a challenge.

- By 2025, > 2,300 km of fully automated metro lines worldwide.
- High-speed and long-distance trains: still no full autonomy.
- Environmental factors and train speed limit transfer of metro automation tech.

The SafeXplain Railway Case Study

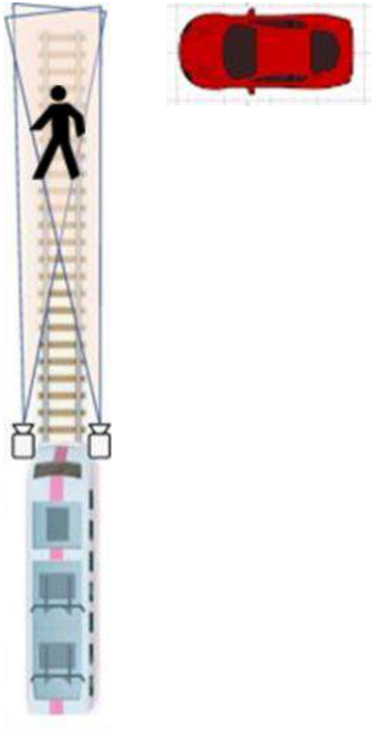
Testing the viability of a **safety architectural pattern** for semi-automatic train operation.

- Employ Deep Learning–based perception (rail segmentation + obstacle detection).
- Ensure safe train operation by detecting obstacles on the rails.
- Provide real-time decision-making with safety guarantees.
- Ensure the system is working under the designed circumstances.

The SafeXplain Railway Case Study

Scenario:

- A semi-automatic driving train, with capabilities to activate service brake, but not the emergency brake.
- Stereo vision, using two cameras.
- Obstacle detection and segmentation
- Control of the braking system

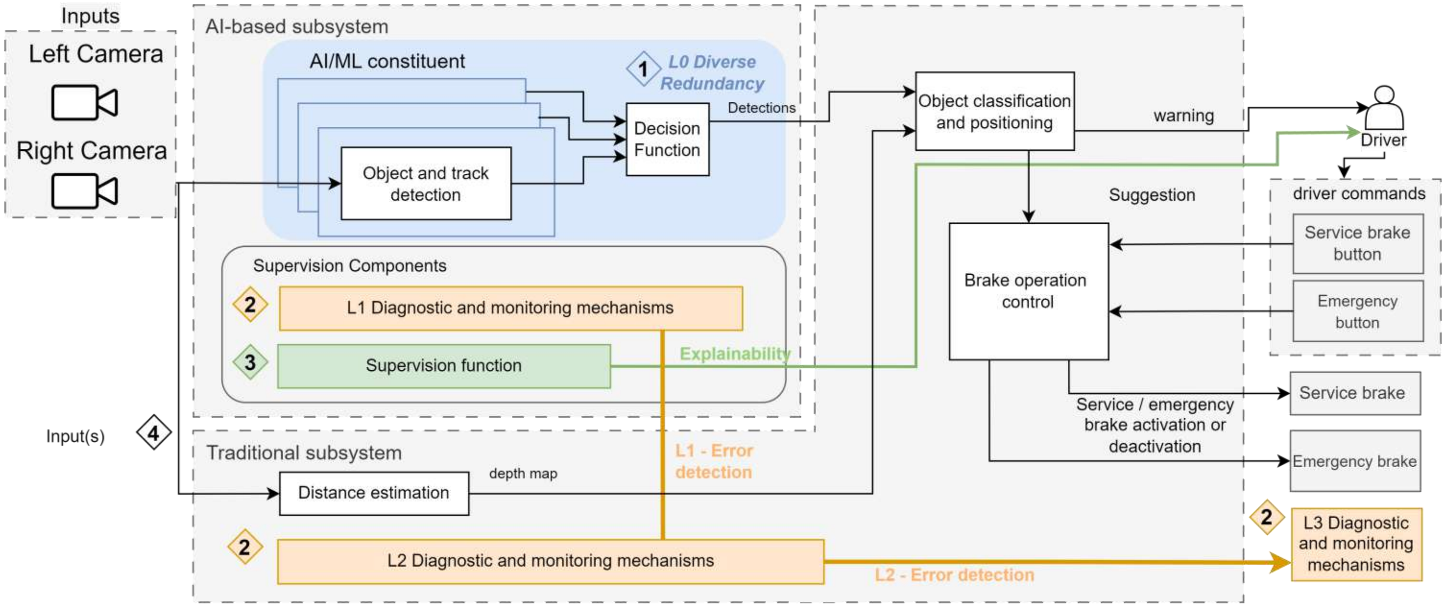


From functions to Architecture

Functions Needed

- Sensing
- Detection
- Distance estimation
- **Diagnostics & monitoring mechanisms**
- Safe braking control system

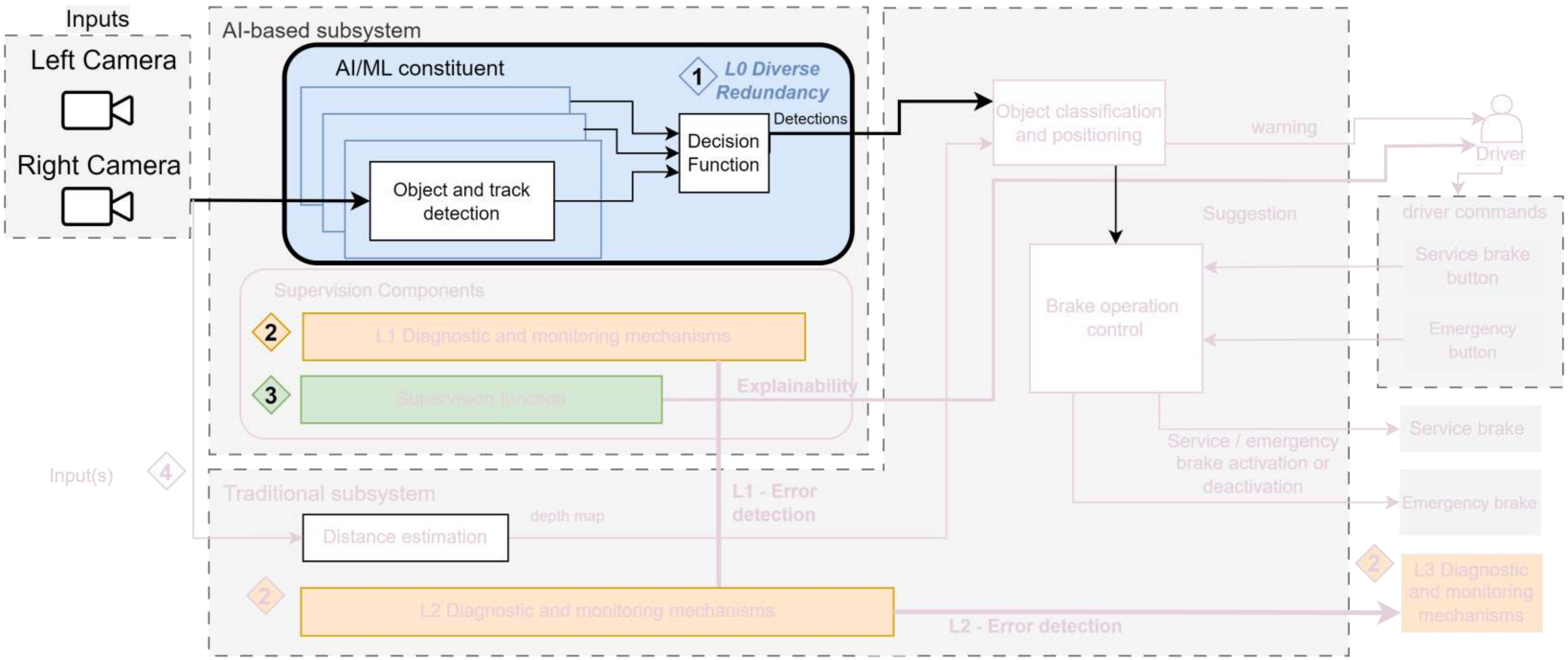
Railway System Architecture



SAFEXPLAIN

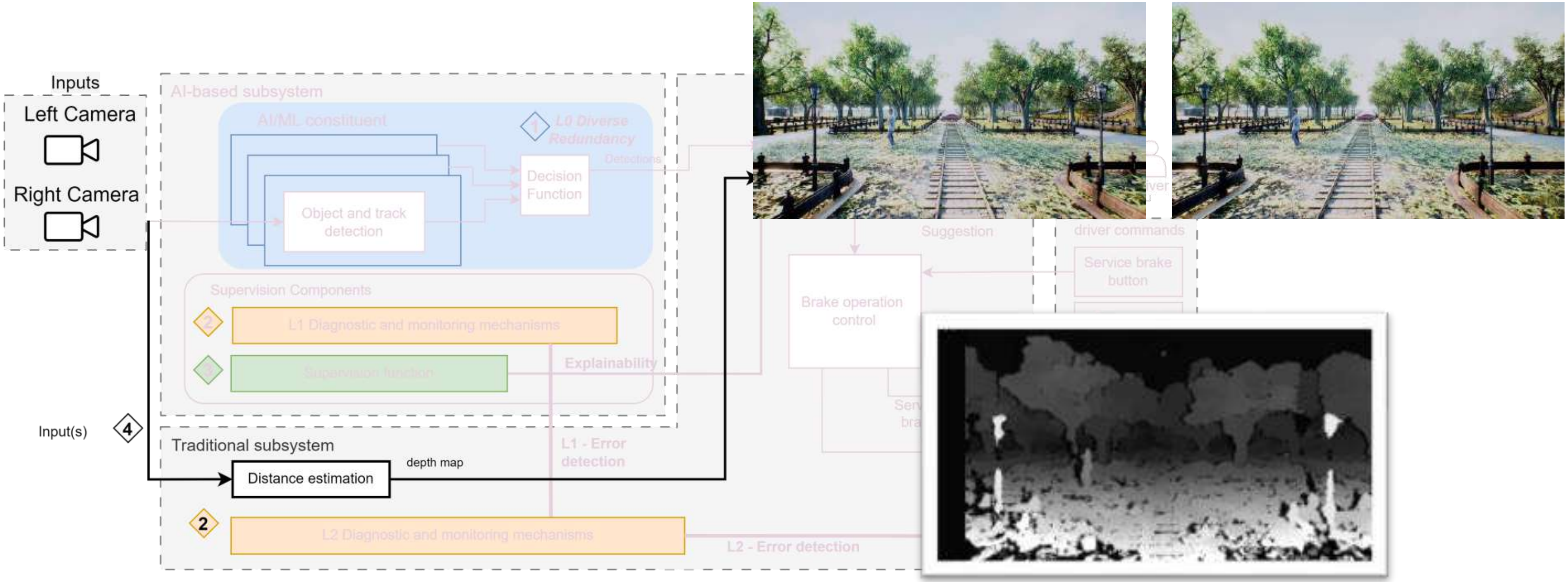
2025/09/23

AI/ML constituent

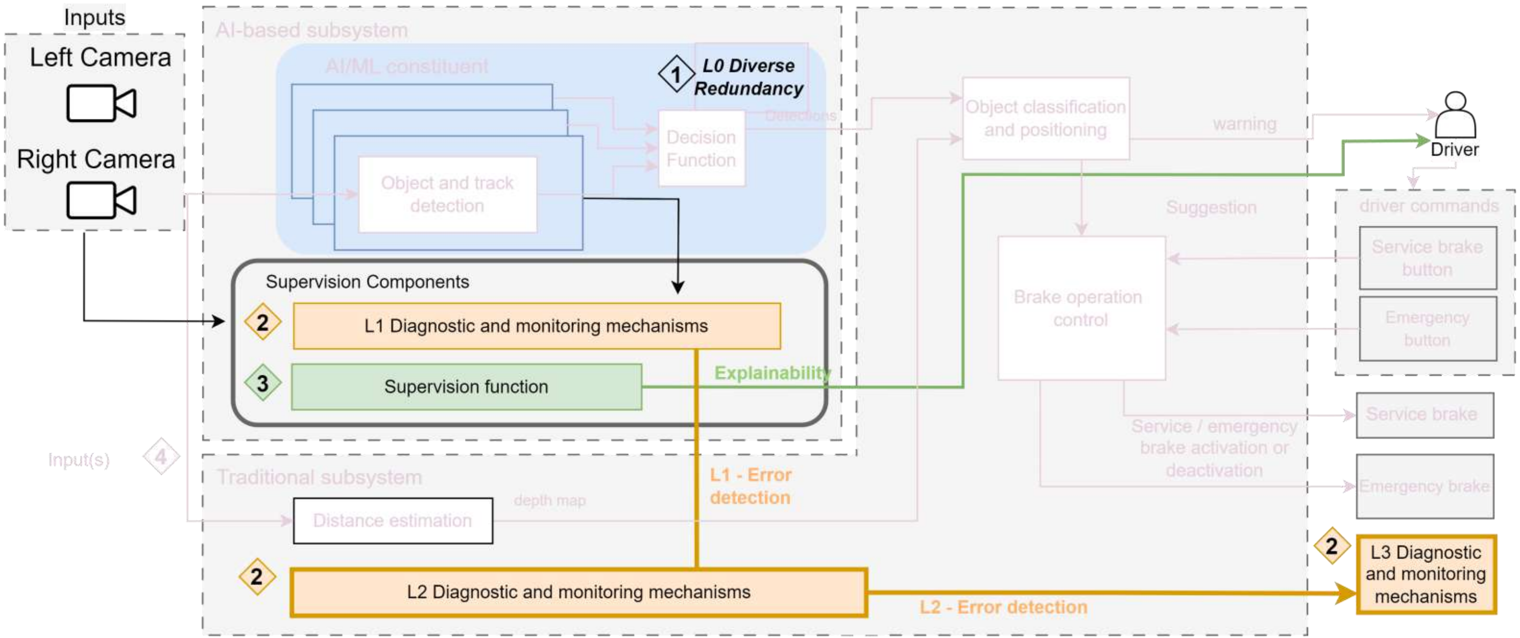


AI/ML constituent - Datasets

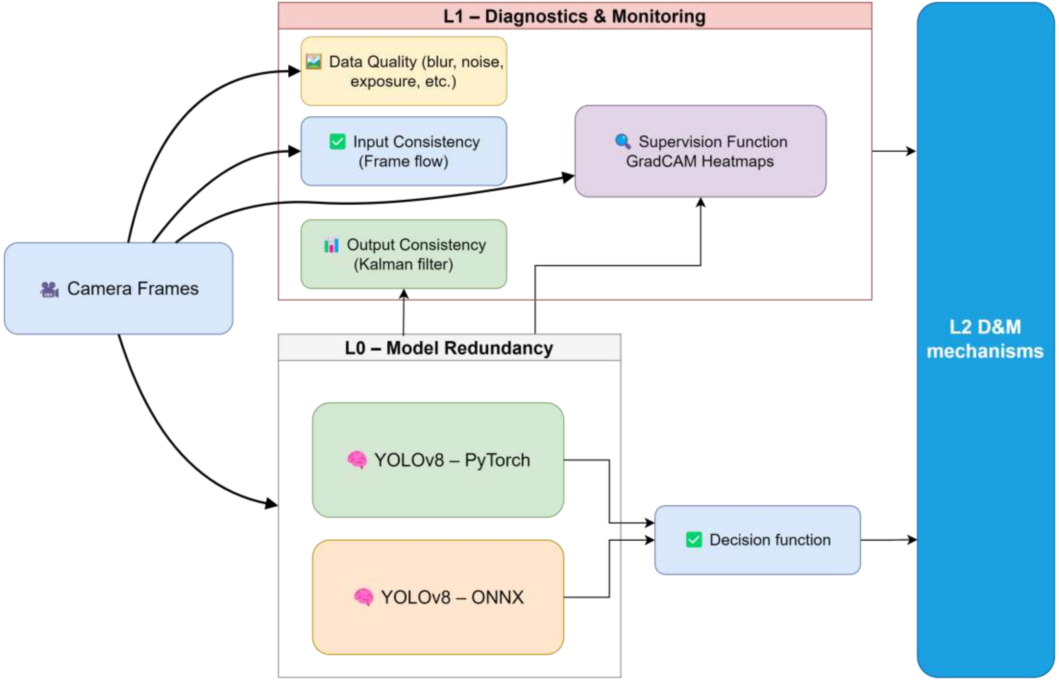
Distance estimation



Diagnostics & monitoring mechanisms



Diagnostics & monitoring mechanisms

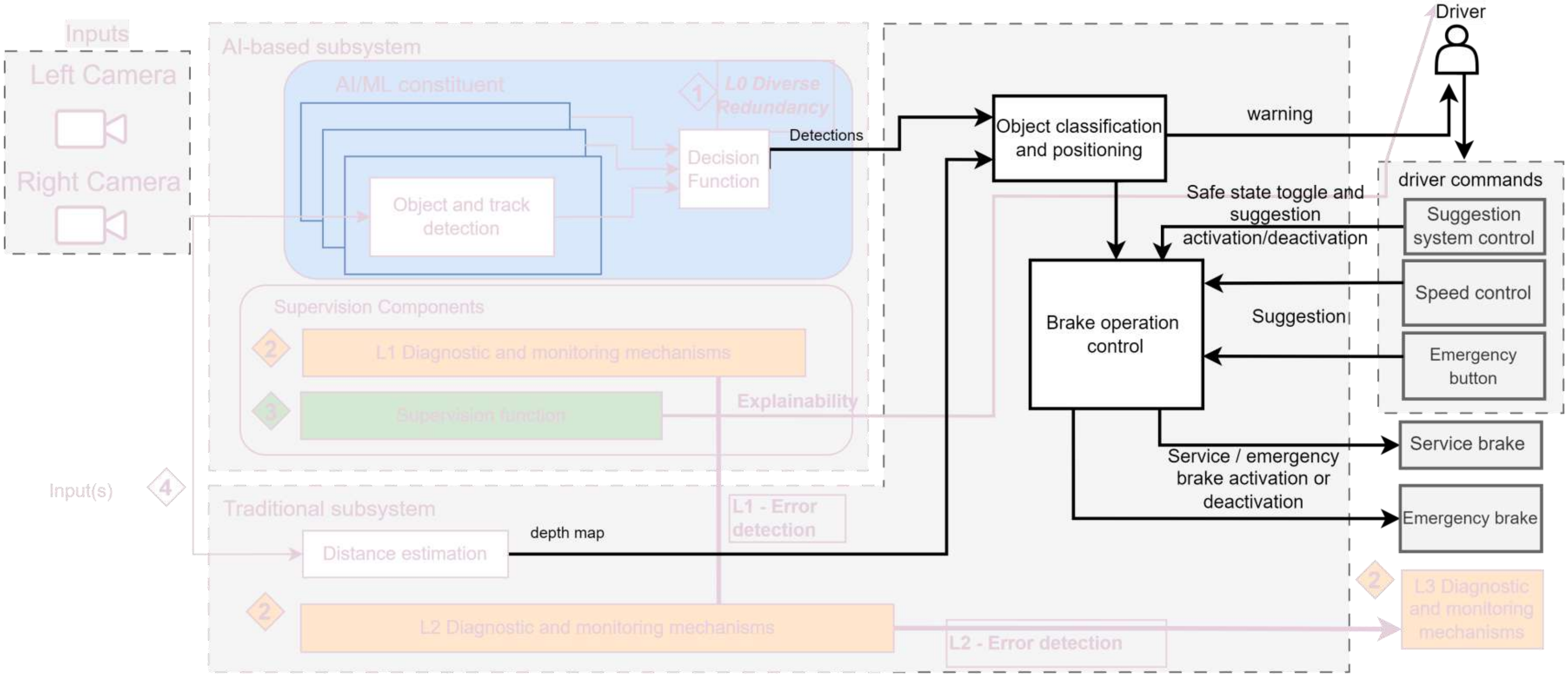


Depending on the outputs of the diagnostics, safe state is activated.

3 not correct frames on the last 8 frames in enough for doing so.

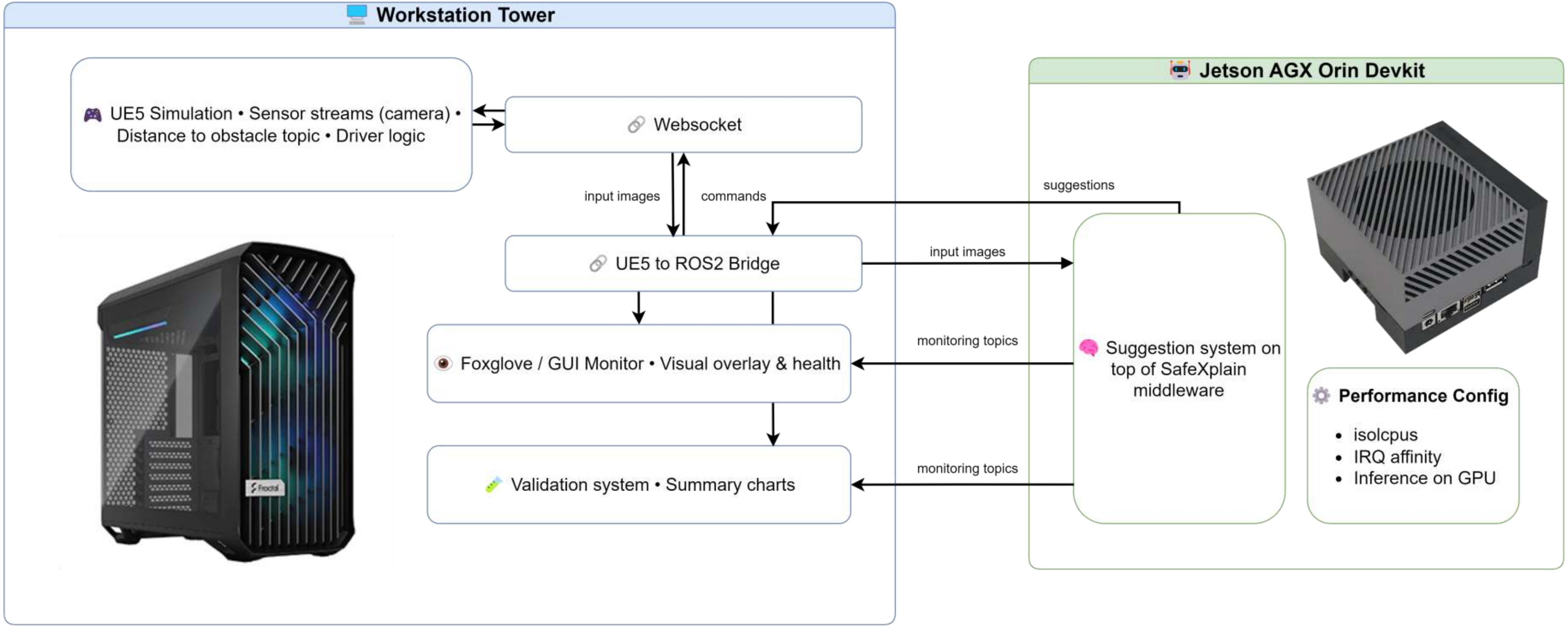
Ensures robustness and sensibility.

Suggestion system and braking control

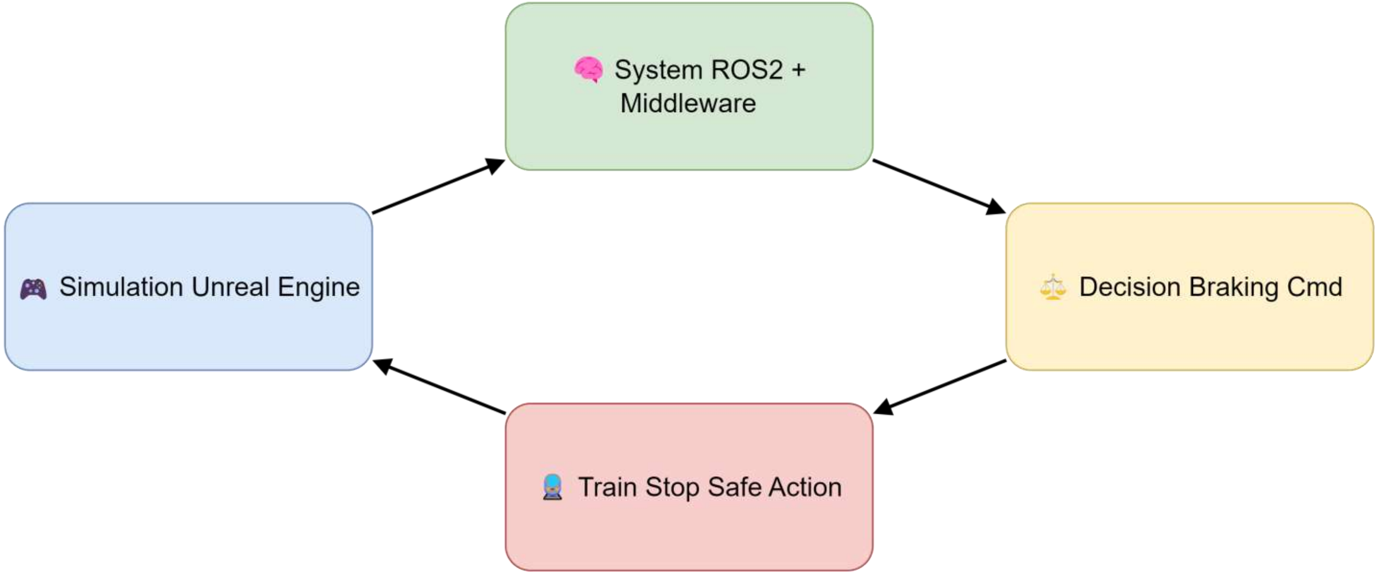


Validation & Execution

Execution Setup

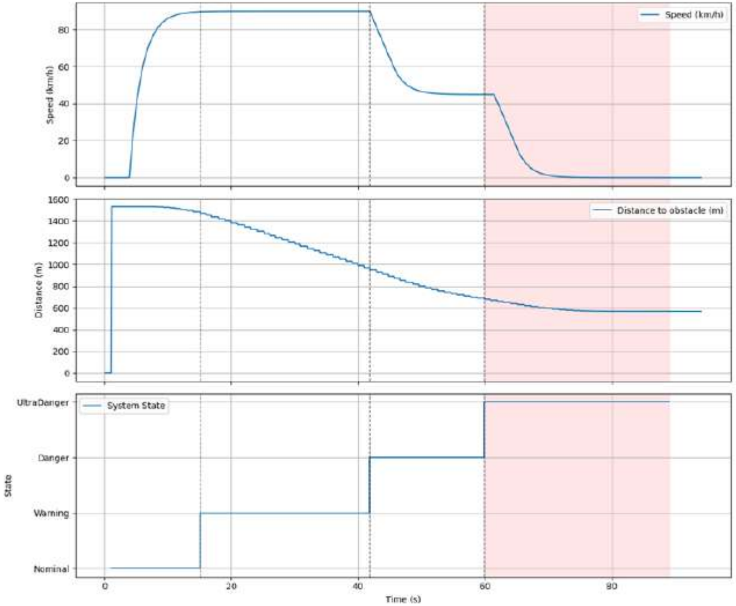


Validation Loop



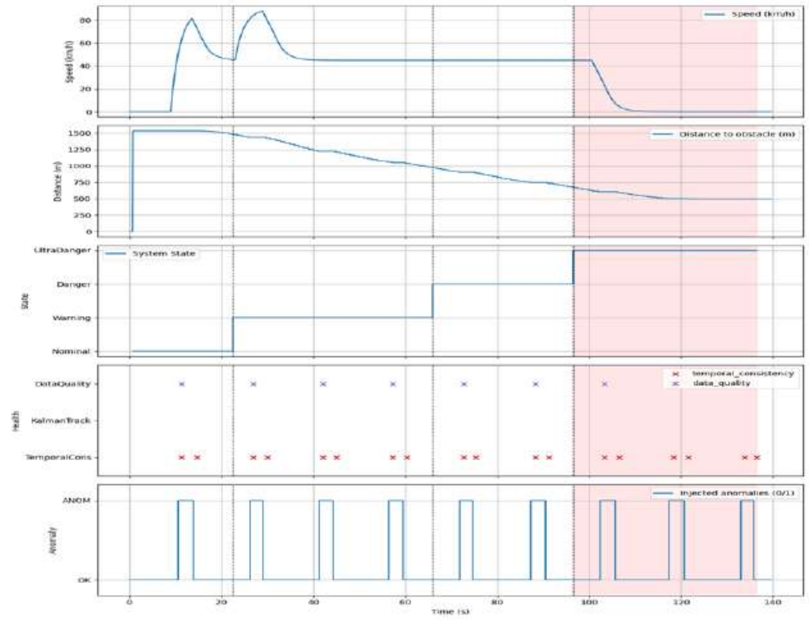
Results Overview – Nominal cases

- Validation has been conducted on daylight conditions.
- All test cases have been concluded correctly.
    - Vehicle on rails
    - Person on rails
    - People on station, outside rails



Results Overview – Anomalous cases

- Multiple injection methods have been tested, to test the robustness of the system.
    - Black frames
    - Frozen frames
    - Corrupt frames
- All test have been correctly passed.



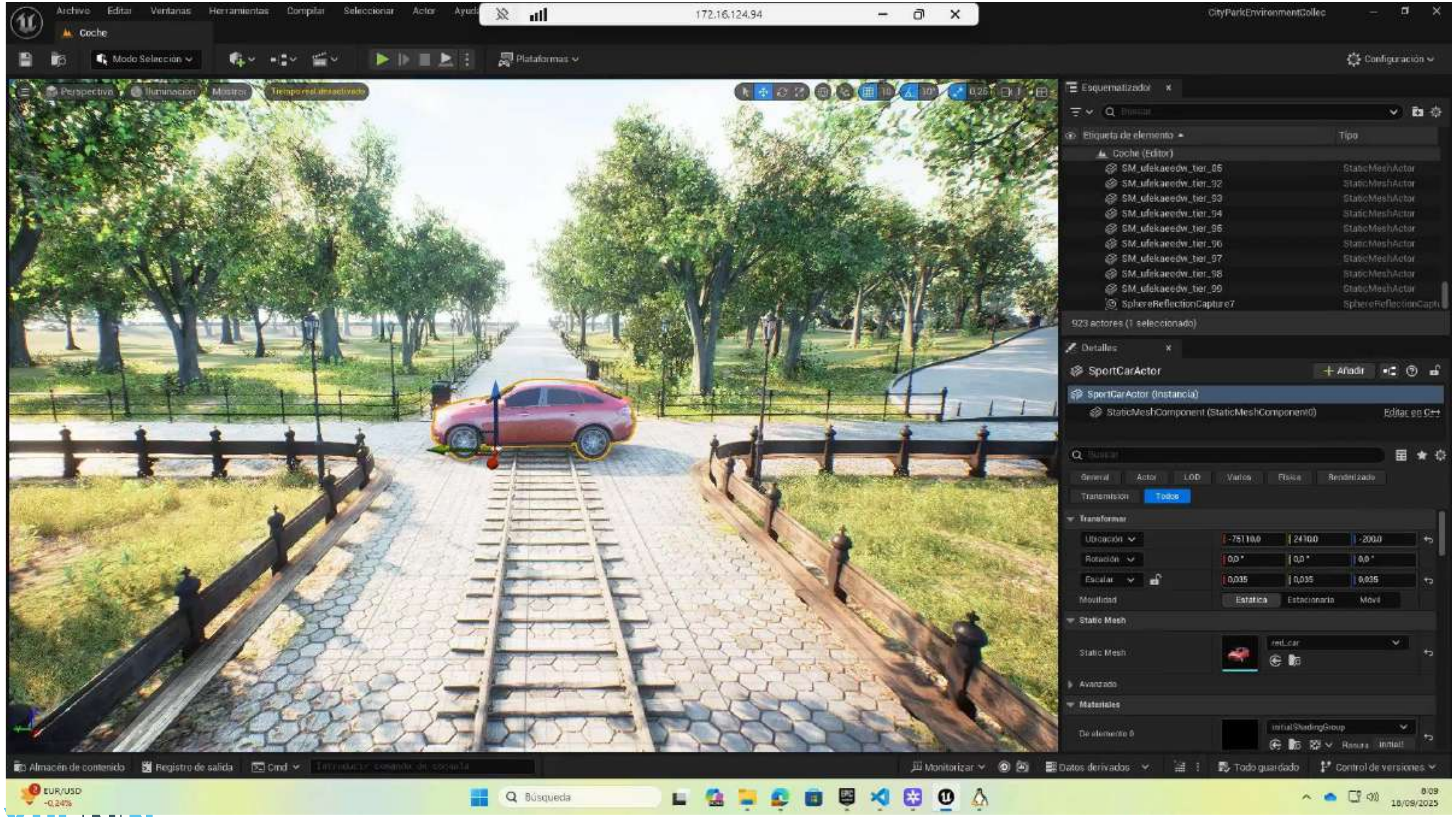
Demonstration

Demo Preview

What we will show you

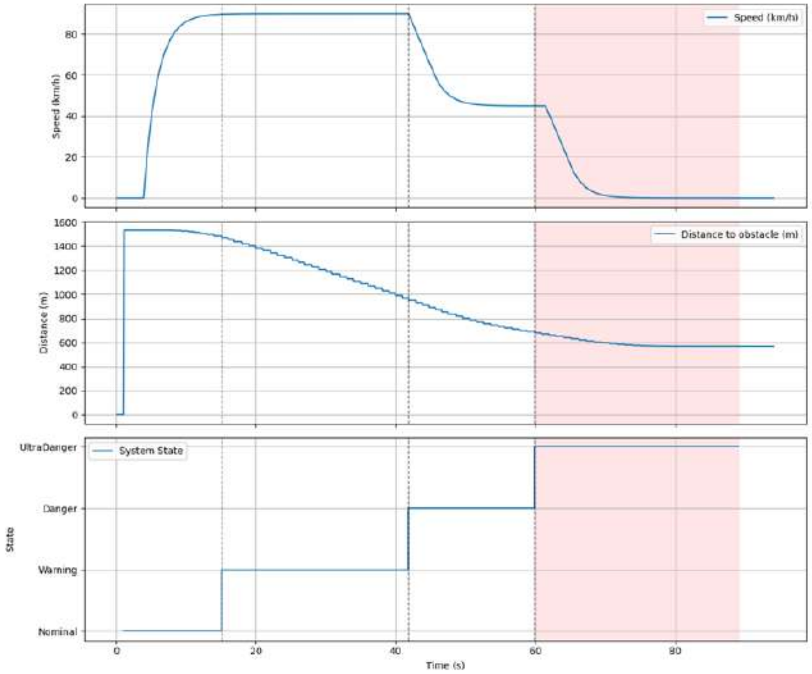
- A stationary car stays on the railway, which is detected and the train is stopped.
- A person stays on the railway, but the system gets faulty input data and needs to go to safe state. The person is detected and a signal is sent to the driver.

Demo video – Car obstacle on railway

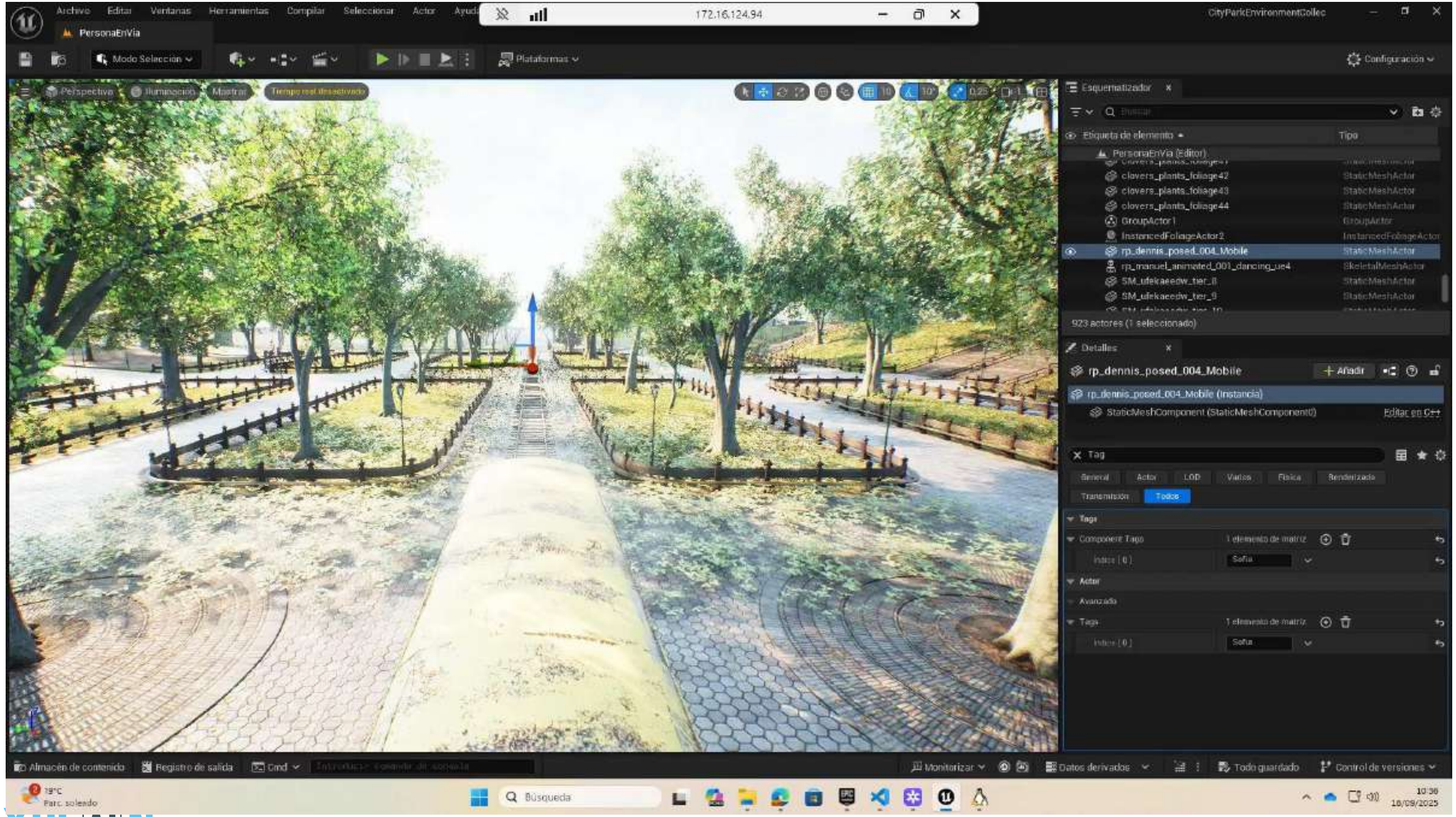


Demo results – Car obstacle on railway

- Detection from far away.
- Service-braking threshold activated at 1000m.
- Danger signal activated in 700m.
- Driver activated emergency braking afterwards.

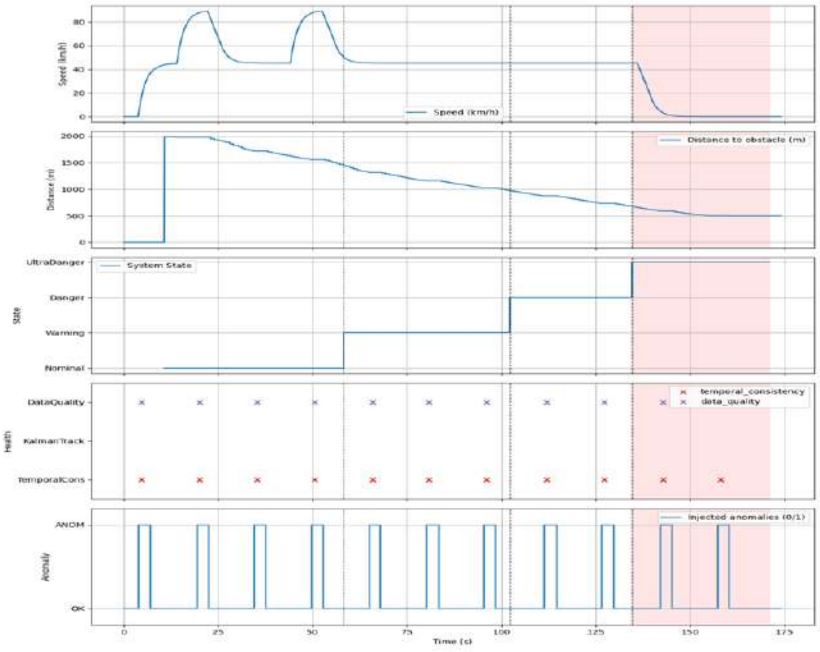


Demo video – Person on railway and corrupt frame



Demo results – Person on railway and black frame

- Anomaly injected every 20s.
- Anomaly correctly detected, and safe state activated from the beginning. Activates service brake.
- Driver deactivates safe state, but system detects again new anomalies so returns to safe state.
- The system is still able to signal that an obstacle is on the track.



Conclusions

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- **Nominal conditions**
  - Consistent and robust performance
  - Timely detections and braking sequences
- **Anomaly injected conditions**
  - Correct detection of anomalies (with safe state activation)
- **Future work**
  - **Detection:** wider scenario validation, with different weather conditions, improved model detection on unseen cases.
  - **Supervision:** faster inference and ability of using it as an anomaly score.
  - **Simulation:** optimisation and automation of scenario generation and validation

Q & A

Safe and Explainable
Critical Embedded Systems based on AI

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