DS3.1 Automotive Safety Demonstration

Safe & Explainable AI for Pedestrian Emergency Braking

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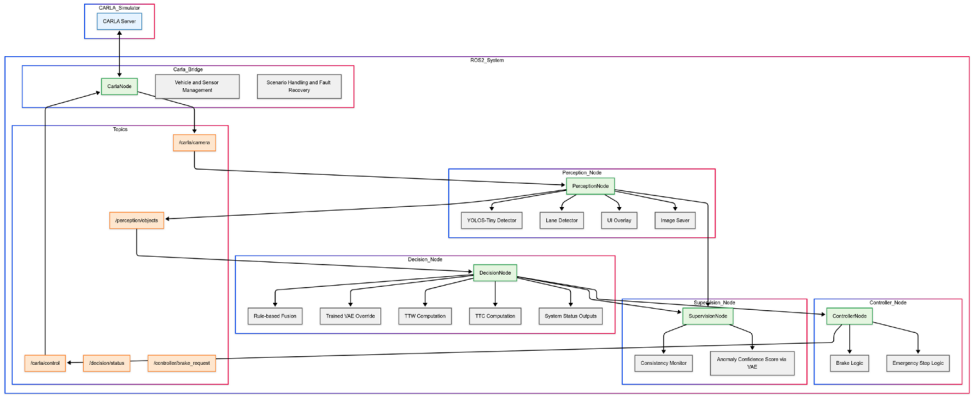
1. System Architecture

- **Perception Node:** YOLOS-Tiny, Lane Detector, Overlay
- **Decision Node:** Rule-based fusion + VAE
- **Controller Node:** Braking logic
- **Supervision Node:** Monitoring + anomaly scoring

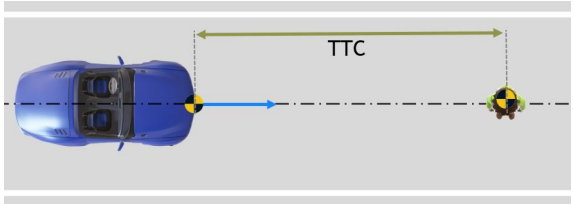


ROS2 DS-3.1 Autonomous Driving Architecture

- **Supportive:** UI Visualization, Warning Sound, Lifecycle Managers

2. Test Framework & Regulations (DS3.1)

- **Step 1:** Approach VRUs (adult, child)
- **Step 2:** Warning at TTW (≥0.8s before braking)
- **Step 3:** Emergency braking at TTC AEB (≥5.0 m/s²)



- **Regulation:** UN R152 clauses 5.2.1.1 & 5.2.1.2
- **SOTIF:** Focus on AI perception limitations

2.2 SOTIF compliant Test Cases(TC's)

NODE	TC-ID	Description	Functionality Validated
Controller	TC1-0005	'Throttle pedal signal is wrongly provided to AEB due to low communication buses performances (e.g. busy buses, inadequate message priority or arbitration or EMI)	YES
Perception	TC1-0019	'Missing object detection due to camera low performances (e.g. damaged lens or untedected offline sensor)	YES
Perception	TC1-0020	Missing object detection due to short or long-term interference condition of the FOV (e.g. dirty window, water, ..)	YES
Supervision	TC1-0022	Too late detection of sensor decrease in performance (e.g. damaged lens, aeging effects, glare conditions, blockage condition of the FOV, extreme weather conditions, wrong camera position/camera calibration...)	YES
Supervision	TC1-0023	Too late detection of a collision relevant object due to inaccurate timestamp synchronization between the ECUs (e.g. object position is wrongly calculated)	YES
Controller	TC1-0024	The object is judged too late as collision relevant due to slow target vehicle's velocity calculation.	YES
Decision	TC1-0024	The object is judged too late as collision relevant due to slow target vehicle's velocity calculation.	YES
Decision	TC1-0025	The object is judged too late as collision relevant due to slow target vehicle's position calculation.	YES
Controller	TC1-0027	The object is judged too late as collision relevant due to slow target vehicle's acceleration calculation.	YES
Perception	TC1-0027	The object is judged too late as collision relevant due to slow target vehicle's acceleration calculation.	YES
Perception	TC2-0001	'Wrong object detection due to wrong camera position/camera calibration (e.g. the sensor is mounted in a wrong position/orientation so not-collision relevant objects could be exchanged as collision relevant)	YES
Decision	TC2-0009	The target object is wrongly detected as collision relevant due to incorrect object velocity calculation.	YES
Decision	TC2-0009	The target object is wrongly detected as collision relevant due to incorrect object velocity calculation.	YES
Perception	TC2-0010	'The target object is wrongly detected as collision relevant due to incorrect object acceleration calculation.	YES
Perception	TC4-0001	'Missing object detection due to camera low performances (e.g. damaged lens or untedected offline sensor)	YES
Supervision	TC4-0001	'Missing object detection due to camera low performances (e.g. damaged lens or untedected offline sensor)	YES
Controller	TC4-0014	'Missing object detection due to camera low performances (e.g. damaged lens or untedected offline sensor)	YES

3. AI & Compute Infrastructure

- **AI Modules:**
  - **YOLOS-Tiny (pedestrian)**
  - **Lane Detector**
  - **VAE (uncertainty)**
  - **Rule-based logic**

- **Execution Mapping:**
  - **GPU:** DL inference, GUI, anomaly detection
  - **CPU:** Decision, supervision, rule-based checks
  - **Middleware:** workload isolation, monitoring

3.1. Real-Time GUI

REAL-TIME GUI

- **Visual outputs:**
  - Bounding boxes & detections
  - Confidence & anomaly scores
  - Time-to-Collision (TTC)
  - System warnings & brake requests

- **Overlay ensures explainability & debugging**

3.2. Overlay GUI functionalities (Pedestrian detection)

Scenario PASS/FAIL result

Object class, distance, confidence

Camera health: Normal/Degraded

Time

Ego velocity

Time To Collision

Brake Request

Reason for braking

Pedestrian Bounding box

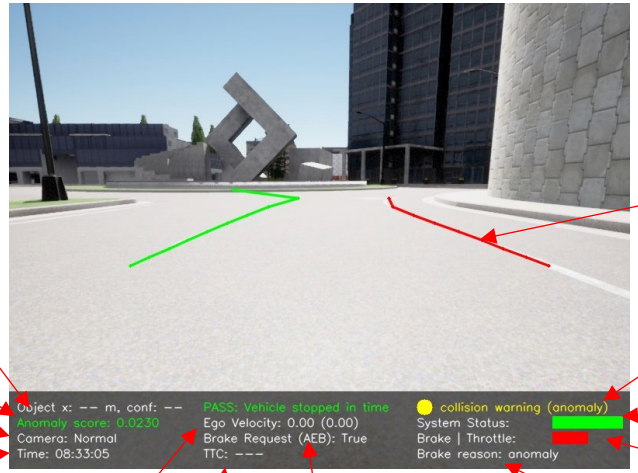
Lane Detector

Collision Warning & Class

System Status Brake/Throttle

3.3. Overlay GUI functionalities (anomaly warning)

- As VAE doesn't do object detection, there is also no TTC. The Anomaly detected is the fountain on the roundabout



Object class, distance, confidence (as no object detected, no info)

Anomaly score (green >= threshold)

Camera health: Normal/Degraded

Time

Ego velocity

Time To Collision

Brake Request

Reason for braking

Brake/Throttle

System Status

Collision Warning & Class

Lane Detector

4. Demonstration Scope

DS3.1
DEMO SCOPE

- **Scenario:** Drive towards pedestrian
- **Conditions:** Day/Night, Dry/Wet, Adult/Child, 10-30-50 km/h
- **Extensions:** Fog, unseen traffic sign, hidden/slow pedestrian

- **Goal:** Warn driver + brake if no reaction

4.1 Test Automation & Analysis

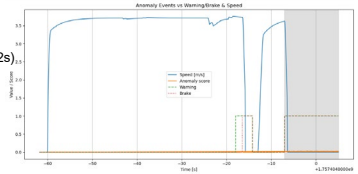
TEST AUTOMATION PIPELINE

- **Step 1:** ROSBAG → MCAP
- **Step 2:** Extract signals (objects, lanes, status, braking)
- **Step 3:** Automated Pass/Fail analysis
- **Step 4:** Reports + graphs

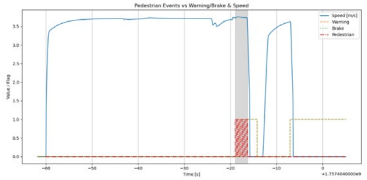
Note: we also do human validation of the failed scenarios

- **Coverage:** 24 scenarios × 5 runs + extras = 150 runs

Anomaly:
Event 1:
- Start offset: 54.75s since sim start
- Span: 1757403992.94s → 1757404005.06s (Δ = 12.12s)
- Max anomaly score: 0.032
- anomaly_score: 0.0261
- Warning at: 1757403992.96s (Δ = 0.02s)
- Brake at: 1757403992.96s (Δ = 0.02s)



Pedestrian:
Event 1:
- Start offset: 42.84s since sim start
- Span: 1757403981.03s → 1757403983.52s (Δ = 2.50s)
- Type Pedestrian confidence 0.98 distance 12.00m
- Warning at: 1757403982.06s (Δ = 1.03s)
- Brake: ❌ none
- ✅ Event OK (no brake/warning conflict)



Examples of graphs & textual output reflecting the anomaly and pedestrian detection in the selected scenario

4.1a Results & Readiness

RESULTS & READINESS

- ✓ Pass/Fail reports confirm (partial) DS3.1 compliance
- ✓ Real-time analytics improve transparency
- ✓ VAE + rule-based fusion add explainability
- ✓ Middleware ensures robustness

- **Conclusion:** Demonstrates explainable, certifiable AI is feasible
- **Observation:** results on Intel and Orin platform seem to be not consistent

Full Test Case List for DS3.1 AEB Scenario						PASS/FAIL RESULTS					
Test Case ID	Carla Town	Lighting	Weather	Pedestrian (5 km/h)	Speed (km/h)	RUN1	RUN2	RUN3	RUN4	RUN5	FINAL Conclusion (%of PASS)
TCDS_3.1-A1	3	Day	Dry	Adult	10	PASS	PASS	PASS	PASS	PASS	100
TCDS_3.1-A2	3	Day	Dry	Adult	30	PASS	PASS	PASS	PASS	PASS	100
TCDS_3.1-A3	3	Day	Dry	Adult	50	PASS[4]	FAIL	FAIL	FAIL	FAIL	20
TCDS_3.1-B1	3	Day	Dry	Child	10	PASS	PASS	PASS[4]	PASS	PASS	100
TCDS_3.1-B2	3	Day	Dry	Child	30	FAIL	PASS	PASS	PASS	PASS	80
TCDS_3.1-B3	3	Day	Dry	Child	50	PASS	PASS[4]	X	PASS[4]	X	100
TCDS_3.1-C1	3	Day	Wet	Adult	10	PASS	PASS	PASS	PASS	PASS	100
TCDS_3.1-C2	3	Day	Wet	Adult	30	PASS	PASS	PASS	PASS	PASS	100
TCDS_3.1-C3	3	Day	Wet	Adult	50	FAIL	FAIL	FAIL	FAIL	PASS[4]	20
TCDS_3.1-D1	3	Day	Wet	Child	10	PASS	PASS	PASS[4]	PASS	PASS[4]	100
TCDS_3.1-D2	3	Day	Wet	Child	30	FAIL	X	X	X	PASS[4]	50
TCDS_3.1-D3	3	Day	Wet	Child	50	PASS[4]	PASS[4]	PASS[4]	PASS[4]	X	100
TCDS_3.1-E1	3	Night	Dry	Adult	10	PASS	PASS	PASS	PASS	PASS	100
TCDS_3.1-E2	3	Night	Dry	Adult	30	X	PASS	X	PASS	X	100
TCDS_3.1-E3	3	Night	Dry	Adult	50	FAIL	PASS[4]	PASS[4]	X	FAIL	50
TCDS_3.1-F1	3	Night	Dry	Child	10	PASS	X	PASS	X	PASS	100
TCDS_3.1-F2	3	Night	Dry	Child	30	PASS	PASS	PASS	PASS	PASS	100
TCDS_3.1-F3	3	Night	Dry	Child	50	PASS	PASS[4]	PASS[4]	PASS[4]	PASS[4]	100
TCDS_3.1-G1	3	Night	Wet	Adult	10	PASS	PASS	PASS	PASS[4]	PASS	100
TCDS_3.1-G2	3	Night	Wet	Adult	30	PASS[4]	X	PASS[4]	PASS	FAIL	75
TCDS_3.1-G3	3	Night	Wet	Adult	50	PASS	PASS	PASS[4]	PASS[4]	FAIL	80
TCDS_3.1-H1	3	Night	Wet	Child	10	PASS	PASS	PASS[4]	PASS	PASS	100
TCDS_3.1-H2	3	Night	Wet	Child	30	PASS	X	X	PASS[4]	X	100
TCDS_3.1-H3	3	Night	Wet	Child	50	PASS[4]	X	PASS[4]	PASS[4]	PASS[4]	100[5]

Test Case List for DS3.1 AEB Scenario (out of scope of DS3.1)						PASS/FAIL RESULTS					
Test Case ID	Carla Town	Lighting	Weather	Class	Speed (km/h)	PASS1	PASS2	PASS3	PASS4	PASS5	FINAL Conclusion (%of PASS)
TCDS_3.1-X1	3	Day	Fog	Adult	10	X	PASS	PASS	X	PASS	100
TCDS_3.1-X2	3	Night	Fog	Adult	10	PASS	PASS	PASS	PASS	X	100
TCDS_3.1-X3	3	Day	Dry	Traffic Sign	10	PASS	X	PASS	PASS	PASS	100
TCDS_3.1-X4	3	Day	Dry	Parked Car	10	PASS	PASS	PASS	X	PASS	100
TCDS_3.1-X5	3	Day	Dry	Slow Adult	10	PASS	PASS	X	X	X	100
TCDS_3.1-X6	3	Day	Dry	Slow Child	10	PASS[4]	PASS	PASS	PASS	X	100

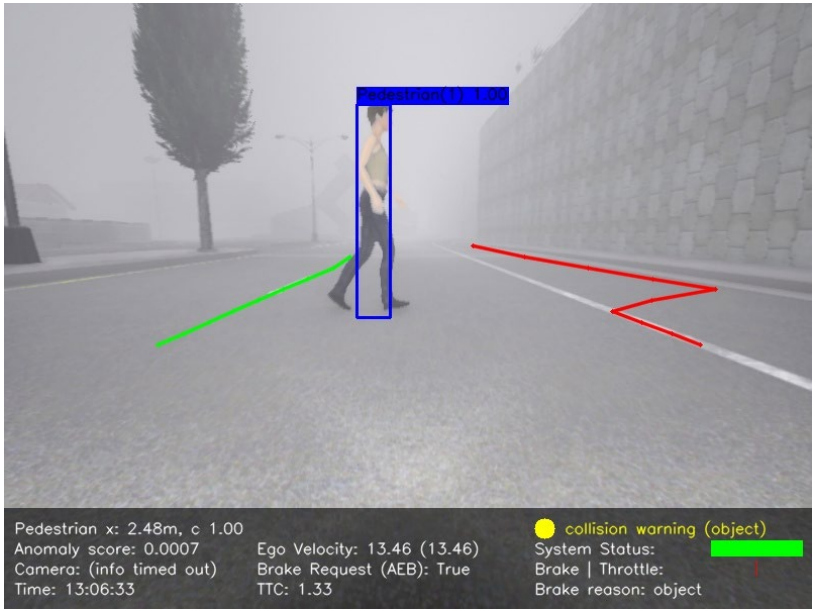
- skid[4] (this means we are braking for a pedestrian crossing the street, do not hit the pedestrian, but only get tot a full stop some distance later)
- Anomaly false postitives[2] (there is a delay caused by anomalies, impacting the opportunity to "meet" the pedestrian on a certain location)
- X[5] (scenario didn't run successfully)

4.2 Beyond the Test Matrix

- Extra scenarios tested: (visuals next slides)
  - Fog (low visibility)
  - Unseen traffic sign 
  - Pedestrian crossing behind car
  - Slow pedestrian

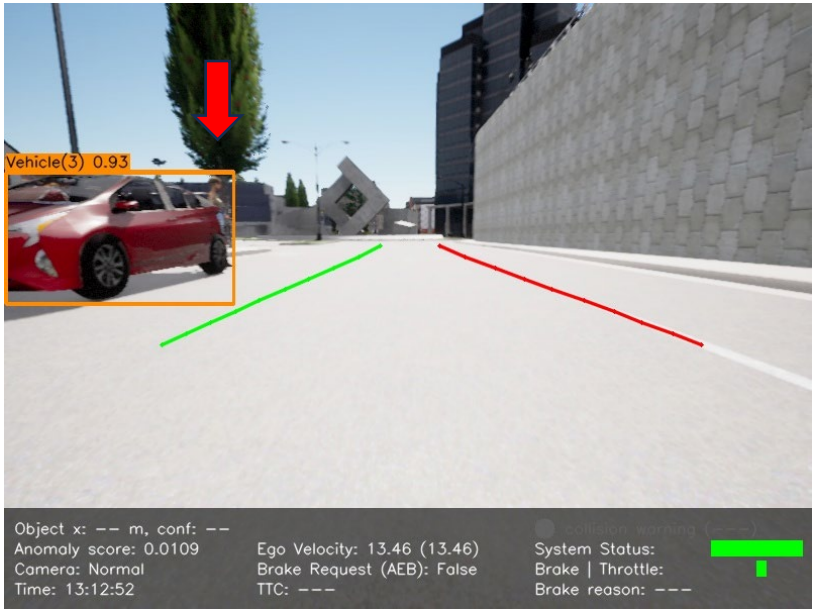
- Validates robustness beyond DS3.1

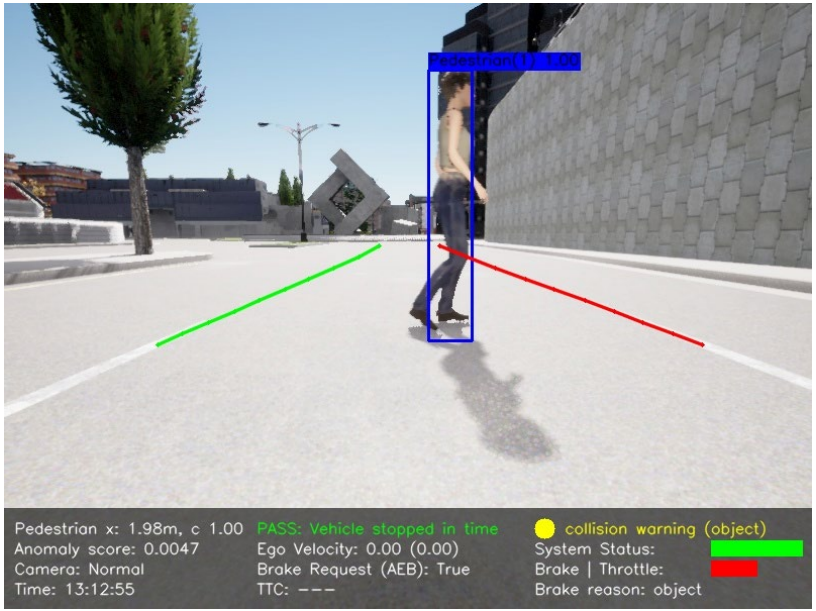
4.2 Beyond the Test Matrix: Fog causing low-visibility



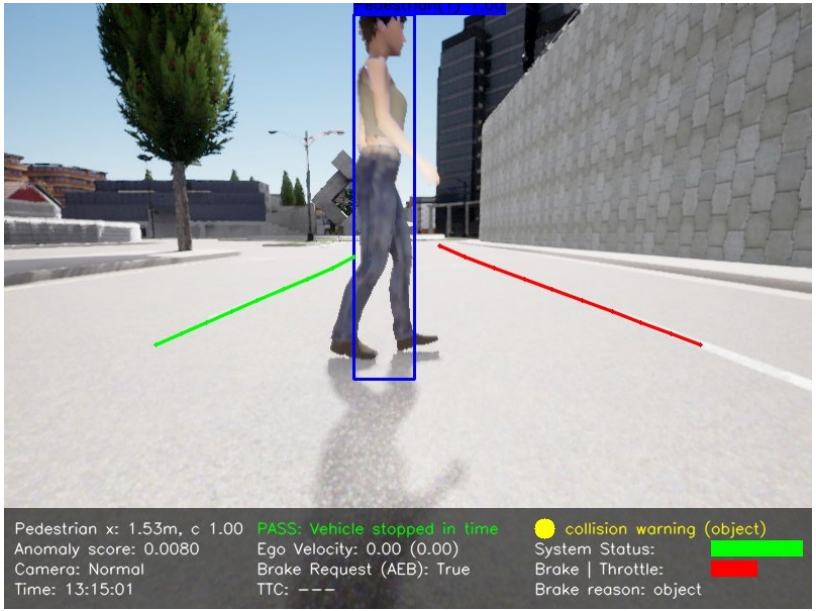
4.2 Beyond the Test Matrix: Caution Sign (Anomaly)

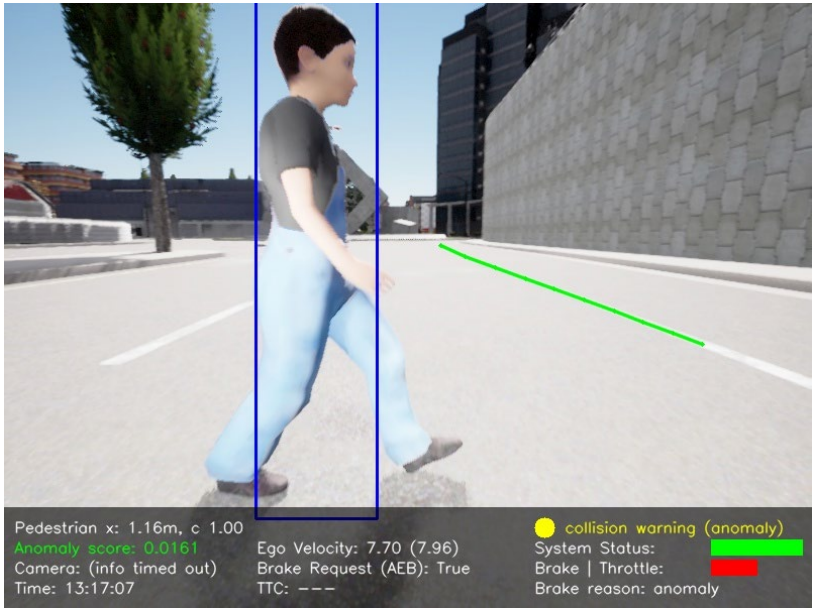
4.2 Beyond the Test Matrix: Pedestrian crossing behind a car





4.2 Beyond the Test Matrix: Slower Pedestrians





4.3 Live Demonstration

- **Runs:**
  - Realtime on ORIN, scenario: Day, Dry, Adult Pedestrian, 10 km/h
    - including warning sound
  - Replay on Foxglove of a MCAP on ORIN, scenario Day, Dry, Adult, 10km/h
  - Replay on Foxglove of a MCAP on ORIN, scenario Day, Wet, Child, 10km/h
  - Replay on Foxglove of a MCAP on ORIN, scenario of unseen traffic sign

Note: We will use the time available to demonstrate as much as possible

Live Demo

5. Conclusion of the AEB Demonstrator (Day vs. Night Performance)

- **Daylight & Dry Conditions**
  - Consistent and robust performance on lower speeds (10/30 km/h)
  - Timely detections and braking sequences
  - Generally compliant with DS3.1 criteria on lower speeds
  - Demonstrator sometimes not able to stop in time on higher speed (50 km/h)
- **Night & Wet Conditions**
  - Reduced sensor reliability and reflections
  - VAE sensitivity in the dark could be improved
  - Warnings and braking often simultaneous → minimal margins, occasional skids
- **Improvements**
  - **Perception:** low-light/wet dataset augmentation, glare reduction, radar/LiDAR fusion, TensorRT model
  - **Supervision:** adaptive anomaly thresholds, dual day/night calibration, uncertainty fusion
  - **Control:** friction-aware braking, predictive stopping distance, enforced warning–brake separation
  - **System:** latency budgeting, scenario-specific calibration

Thank you for your attention, Questions?

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