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Apparent Wind & Weather Sensing:

Enabling Safer, More Efficient Connected Vehicles and Certified Test Beds

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windpuls

> "Track and road tests are biased by micro-weather and inconsistent states."
>
> Dr. Christoph Feichtinger

windpuls ***testing and validation suite***

simonaero

... makes decisions fair, repeatable and explainable.

The windpuls test and validation suite, simonaero, is a unified pipeline designed to enable sustainable, data-driven decisions. It brings together multiple disciplines under expert guidance to transform raw data from test tracks and real-world driving into clear, repeatable A/B insights. By precisely modeling apparent wind and normalizing results across varying operating conditions, simonaero isolates true vehicle effects from environmental noise. The result is a set of explainable KPIs and intuitive decision cards that accelerate development and strengthen confidence in every outcome. As a central hub for informed decision-making, simonaero connects teams and expertise across domains — empowering engineers to make faster, smarter and more sustainable choices for the long term.

INGEST

The simonaero pipeline ingests data from GNSS/IMU/CAN systems (capturing performance and vehicle data), lap timing, and windpuls sensors to enable comprehensive vehicle testing analysis. This data undergoes health and synchronization checks to ensure quality before being processed through subsequent pipeline stages.

STATE

The simonaero state machine segments driving patterns into predefined categories: Straight, Brake, Corner, Steady-Speed, Lean Angle, Acceleration, and Dynamic State. The system ensures complete coverage by identifying appropriate and meaningful state ranges for the entire measurement, with every driving situation assigned to a defined segment and no undefined gaps.

WIND

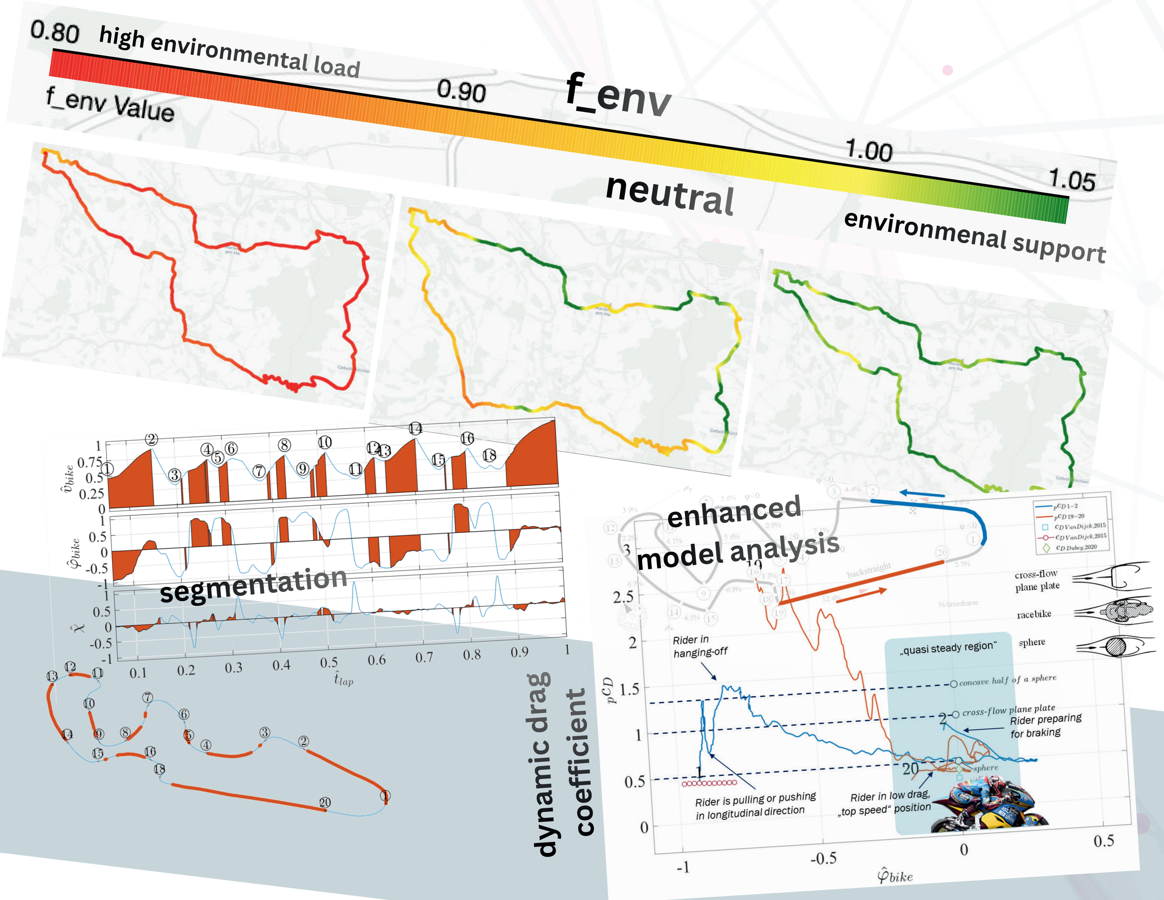
The simonaero Wind stage computes the apparent wind vector and crosswind exposure (Seitenwind-Exposition, SE) from the vehicle-relative airflow measured during each driving state. It also calculates Gust Index (GI) and Turbulence Intensity (TI) to quantify wind variability and turbulence, enabling fair A/B comparisons by accounting for micro-weather conditions that bias test results.

ANALYSIS

The Analysis stage performs segment-based KPI calculations using both simple and enhanced physical models, leveraging all available data to compute metrics like cDA, CO2, Cost of Transportation or ODD-Touch-Rate, etc. based on user requirements. It then applies model-aware corrections using wind covariates to account for environmental biases and ensure fair A/B comparisons.

DECISION

The Decision stage computes A/B deltas for each state cluster using bootstrap confidence intervals to quantify uncertainty. It then generates a Decision Card displaying the result with acceptance criteria and statistical confidence, such as whether to accept $\Delta Cd = -0.014 \pm 0.001$ with 92% confidence.



FULL SPEED AHEAD:
AI AT THE WHEEL
EYES ON THE WIND

exemplary

USE-CASE SPECIFIC DECISION CARDS:

ODD Touch Rate (ADAS Disengagement) — ADAS

Target: Reduce driver takeover rate in Operational Design Domain (ODD) by ≤15% to improve ADAS confidence
Setup: ADAS Calibration A (standard crosswind threshold) vs. Calibration B (simonaero wind-adaptive threshold)
Conditions: Public highway, 500 km per calibration, crosswind-prone sections, 10 test drivers
Wind Context: Both calibrations tested under similar SE (2.8–3.2 m/s) and TI (0.18–0.22)
Result: ACCEPT — ODD Touch Rate reduced by 18% ± 4% (from 12 to 9.8 disengagements per 100 km)
Confidence: 93% CI [10%, 26%]
Decision: Wind-adaptive thresholds significantly reduce unnecessary takeovers without compromising safety margins. Recommend certification testing for production release.

Environmental Impact Factor (EIF) — Range Estimation — EVS

Target: Improve EV range prediction accuracy by ≥10% to reduce range anxiety and optimize charging strategy
Setup: Range Algorithm A (static wind model) vs. Algorithm B (simonaero real-time wind integration)
Conditions: 50 EVs, 150 km rural/highway routes, various wind conditions over 4 weeks
Wind Context: Algorithm B dynamically adjusted for SE (1.5–4.2 m/s), GI (0.22–0.41), TI (0.10–0.28)
Result: ACCEPT — Range prediction error reduced by 14.3% ± 2.8% (from ±18 km to ±15.4 km average deviation)
Confidence: 96% CI [8.7%, 19.9%]
Decision: Real-time wind-aware range estimation significantly improves user confidence and reduces emergency charging events. Deploy as OTA update with driver-facing EIF transparency (e.g., "Headwind detected: -8% range impact").

ΔCd (Aerodynamic Drag Coefficient) — AERO

Target: Reduce drag coefficient by ≥2% to improve highway fuel efficiency
Setup: Configuration A (baseline front bumper) vs. Configuration B (optimized air dam)
Conditions: Test track, 15 laps each configuration, ambient temp 18–22°C
Wind Context: SE (Crosswind Exposure) A: 2.1 m/s, B: 2.4 m/s; TI (Turbulence) A: 0.12, B: 0.14
Result: ACCEPT — $\Delta Cd = -2.8\% \pm 0.6\%$ (wind-adjusted)
Confidence: 95% CI [-3.4%, -2.2%]
Decision: Configuration B shows statistically significant drag reduction even after accounting for higher crosswind exposure. Recommend production validation.

Cost of Transport / CO_2 Emissions — LOGISTICS

Target: Reduce energy cost per km by ≥5% to lower fleet operating costs and CO_2 footprint
Setup: Fleet A (standard route planning) vs. Fleet B (wind-optimized routing via simonaero)
Conditions: 200 km mixed urban/highway routes, 30 vehicles per fleet, 2-week trial
Wind Context: Fleet B encountered 8% higher average headwind but optimized speed profiles
Result: ACCEPT — Cost of Transport reduced by 6.2% ± 1.1%; CO_2 emissions down 5.8 kg/vehicle/day
Confidence: 98% CI [4.1%, 8.3%]
Decision: Wind-aware routing delivers measurable efficiency gains despite higher headwind exposure. Scale to full fleet with seasonal recalibration.

A unified pipeline for ***sustainable decisions,***
blending disciplines *with* ***expert guidance.***

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Scan the QR code to access a sub-dataset from this study.