ETH – SBB Mobility Initiative OMISM

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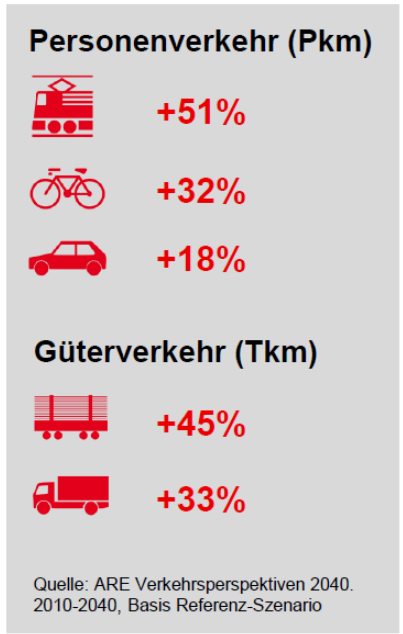
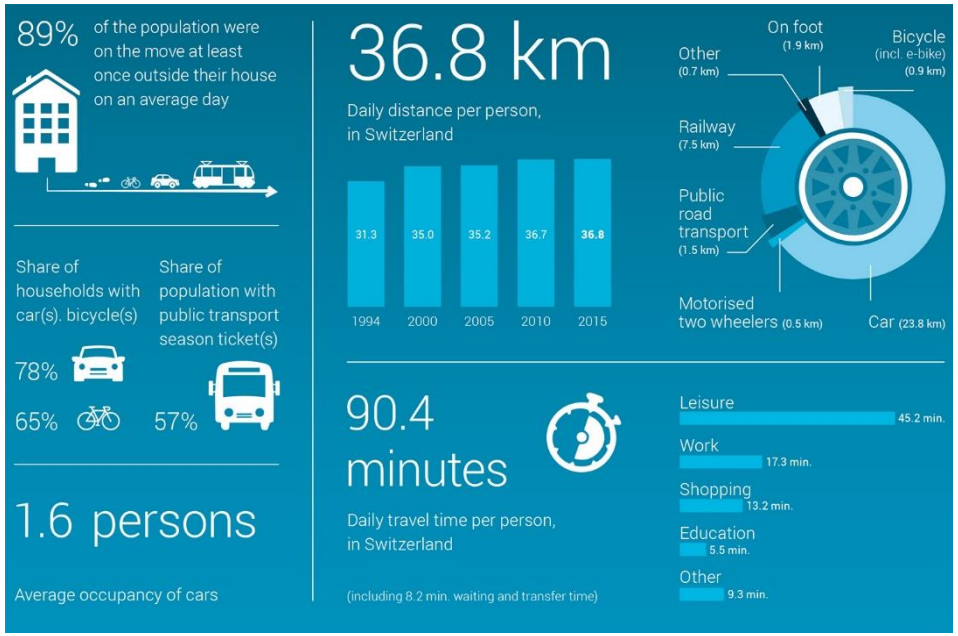
SBB: Aurelia Kollros, Marcel Zurkirchen, Thomas Wissart, Thomas Luksch, Lucian Ancu

May 5th 2022, Sustainable Future Mobility 2022 Conference

Background & motivation



Vison und Strategie der SBB (2017).



MMTC (2015).

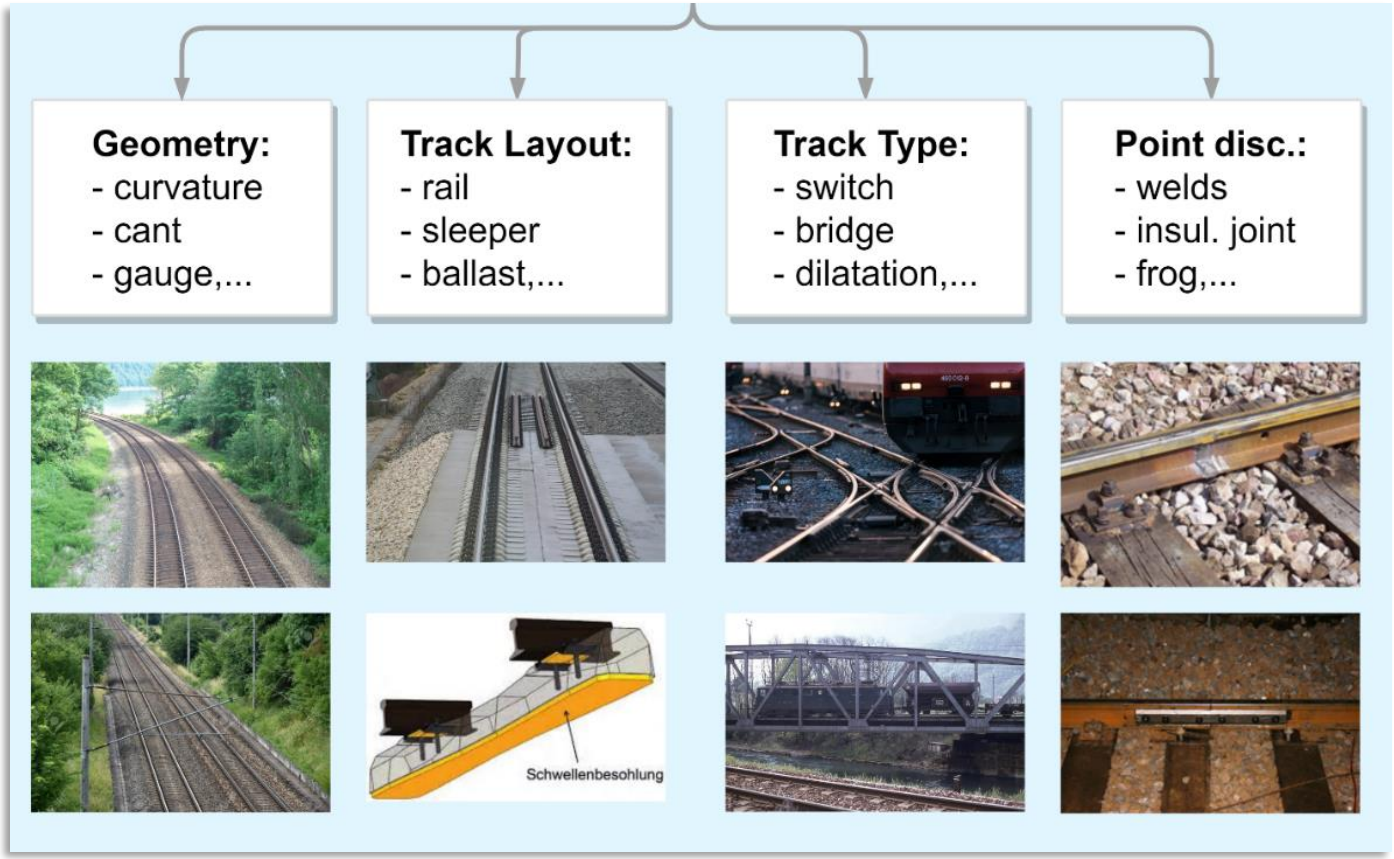
The **increasing** demand in cost efficiency is one of the biggest challenges Switzerland currently faces in view of the current economic situation.

(Vision Mobilität Schweiz 2050).

Managing the Operation & Maintenance of Railway Infrastructure

Guaranteeing Safety & Resilience

Mutli-Component Infrastructure

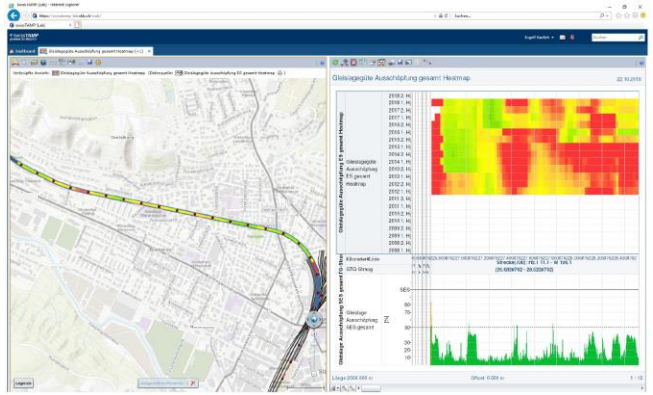


Industrialization and digitalization of railway monitoring

Traditional

Industrial

On Board Monitoring



Online Monitoring & Decision aid

The OMISM framework – Exploitation of On Board Monitoring (OBM) Data

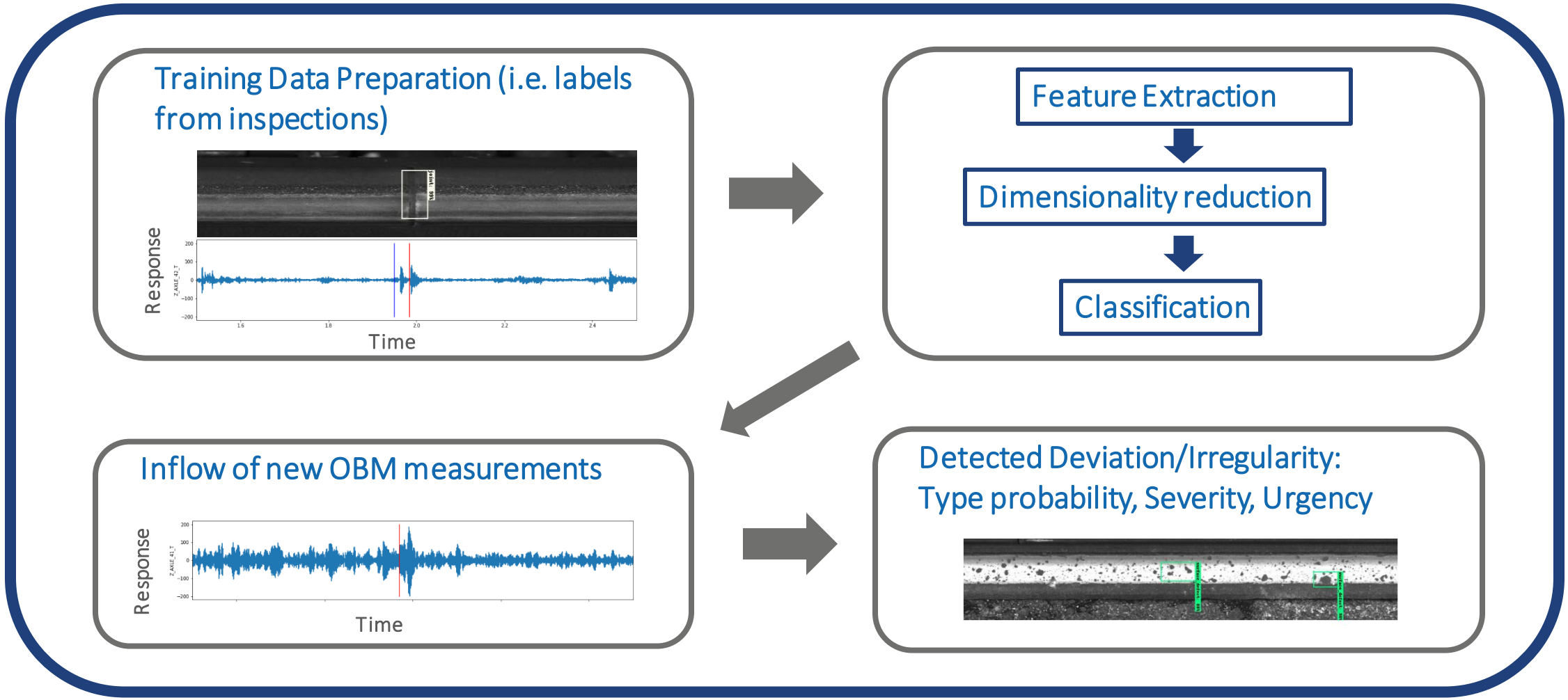
Improve performance, predictive ability & system understanding

Safety | Reliability | Availability | Riding Comfort

Reduce Life Cycle Costs operation & maintenance

Pillar I: OBM-based Condition Indicators for Railway Infrastructure

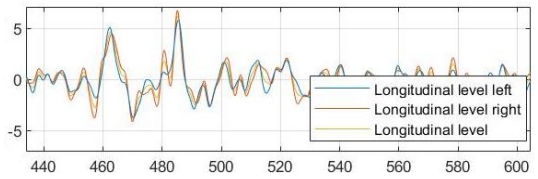
Data-Driven Assessment



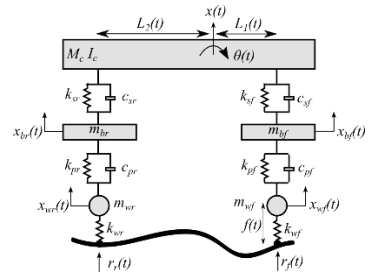
Cyprien Hoelzl, Vasilis Dertimanis, Matthias Landgraf, Lucian Ancu, Marcel Zurkirchen, Eleni Chatzi, Chapter 9 - On-board monitoring for smart assessment of railway infrastructure: A systematic review, The Rise of Smart Cities, Butterworth-Heinemann, 2022

Fusion of Models with Data (Hybrid approach) / Vehicle – Track Simulation Models

Track Geometry, Excitation, Rail Profile,...

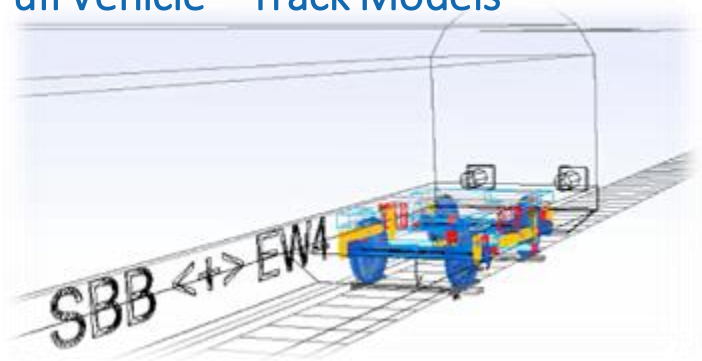


Reduced Order Models



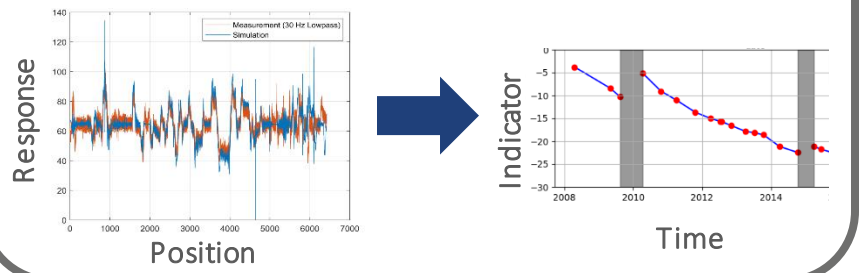
Fusion with data via Bayesian Filters - online

Full Vehicle – Track Models



Fusion with data via Model Updating (offline)

Simulation, Inference, Extrapolation & Predictions

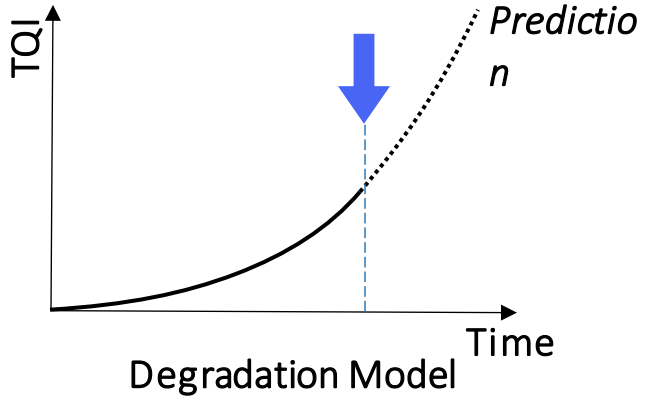


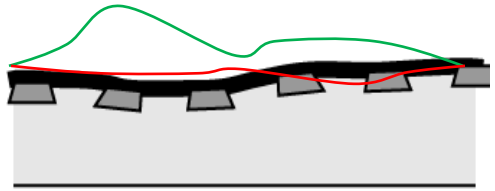
Hoelzl, C.A., Valencia, L.D.A., Dertimanis, V.K., Chatzi, E.N., Zurkirchen, M. (2020). Axle Box Accelerometer Signal Identification and Modelling. Volume 3. Conference Proceedings of the Society for Experimental Mechanics Series

Pillar II: System understanding & Management

Pillar II Framework

Estimating track quality based on Track Quality Index (TQI)





Using TQIs to estimate the degradation model for the multiple tracks

Estimating various costs and maintenance effects

Developing mathematical models for maintenance & inspection scheduling

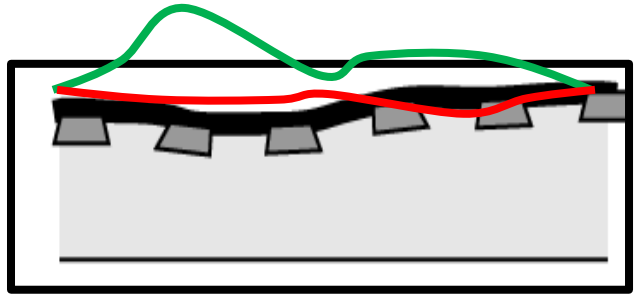
Cost for maintenance, availability, reliability
Estimating the recovery effect of maintenance
Estimating the relation between track status and system failure, drivers reaction, system availability

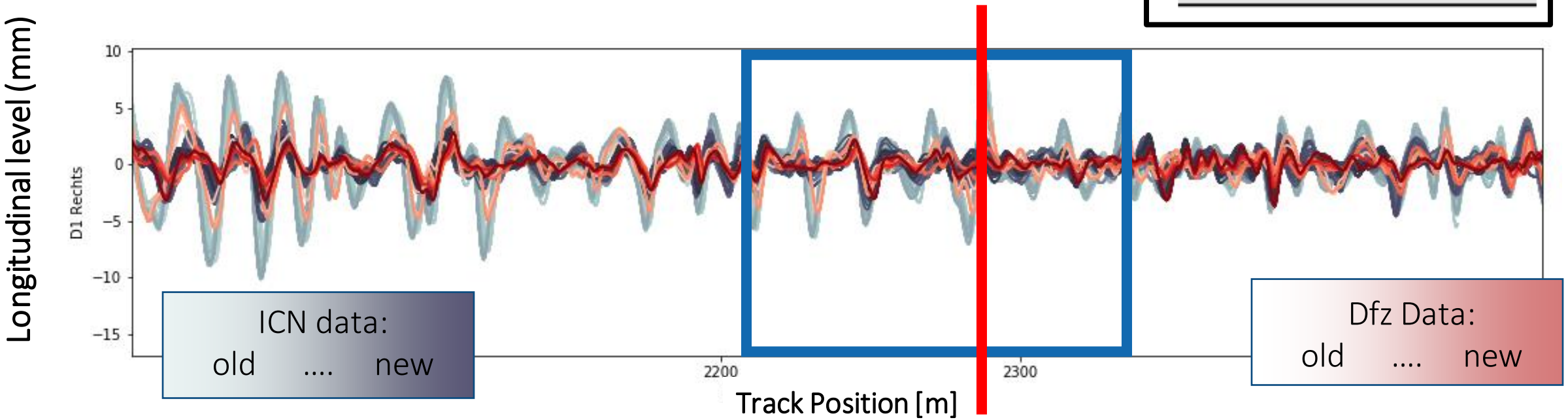
Selected Outcomes/Results

Continuous Track Geometry Monitoring from OBM ICN Accelerations

A straightforward condition indicator may be obtained by simply integrating twice the OBM accelerations. This offers an approximation of the Longitudinal level (LL) – track irregularity.

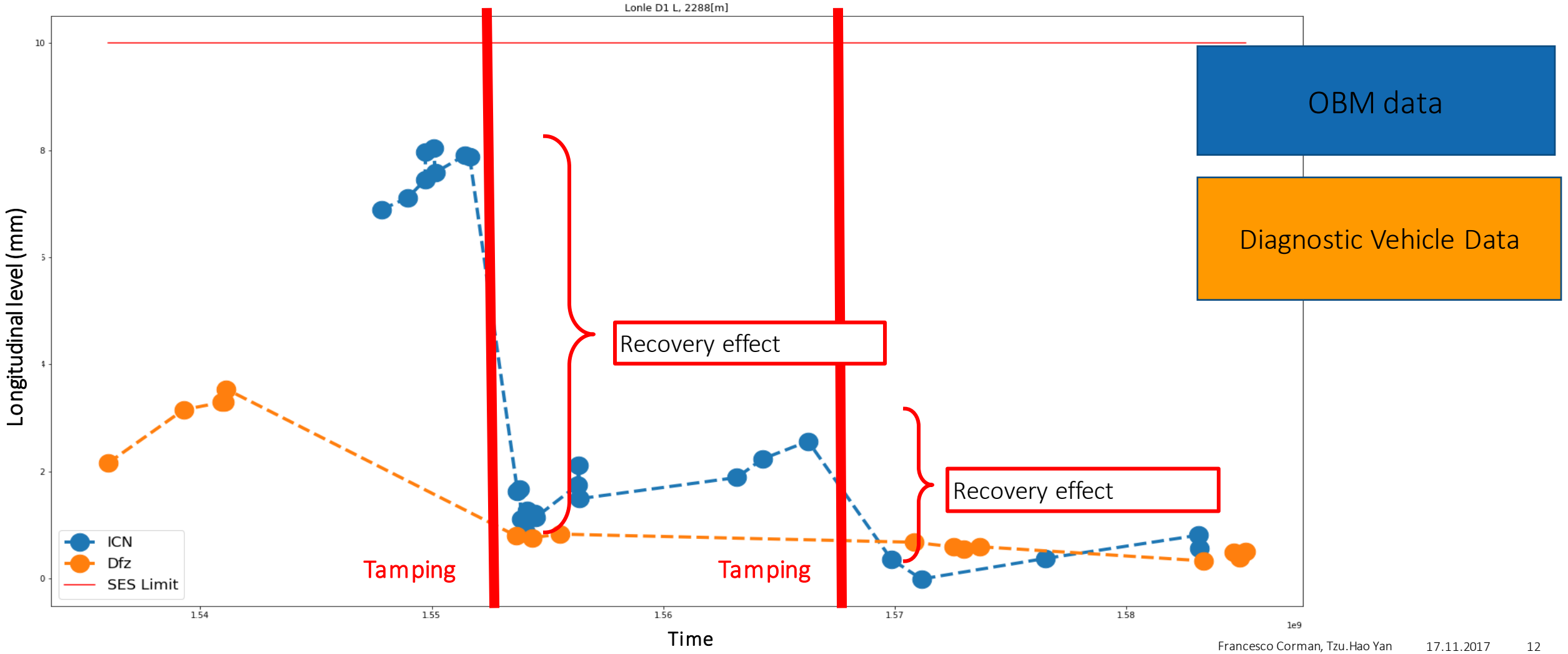
*The use of ICN (in service trains) involves lower cost sensors than specialized diagnostic vehicles (DFZ) and could offer continuous monitoring of extended track sections.





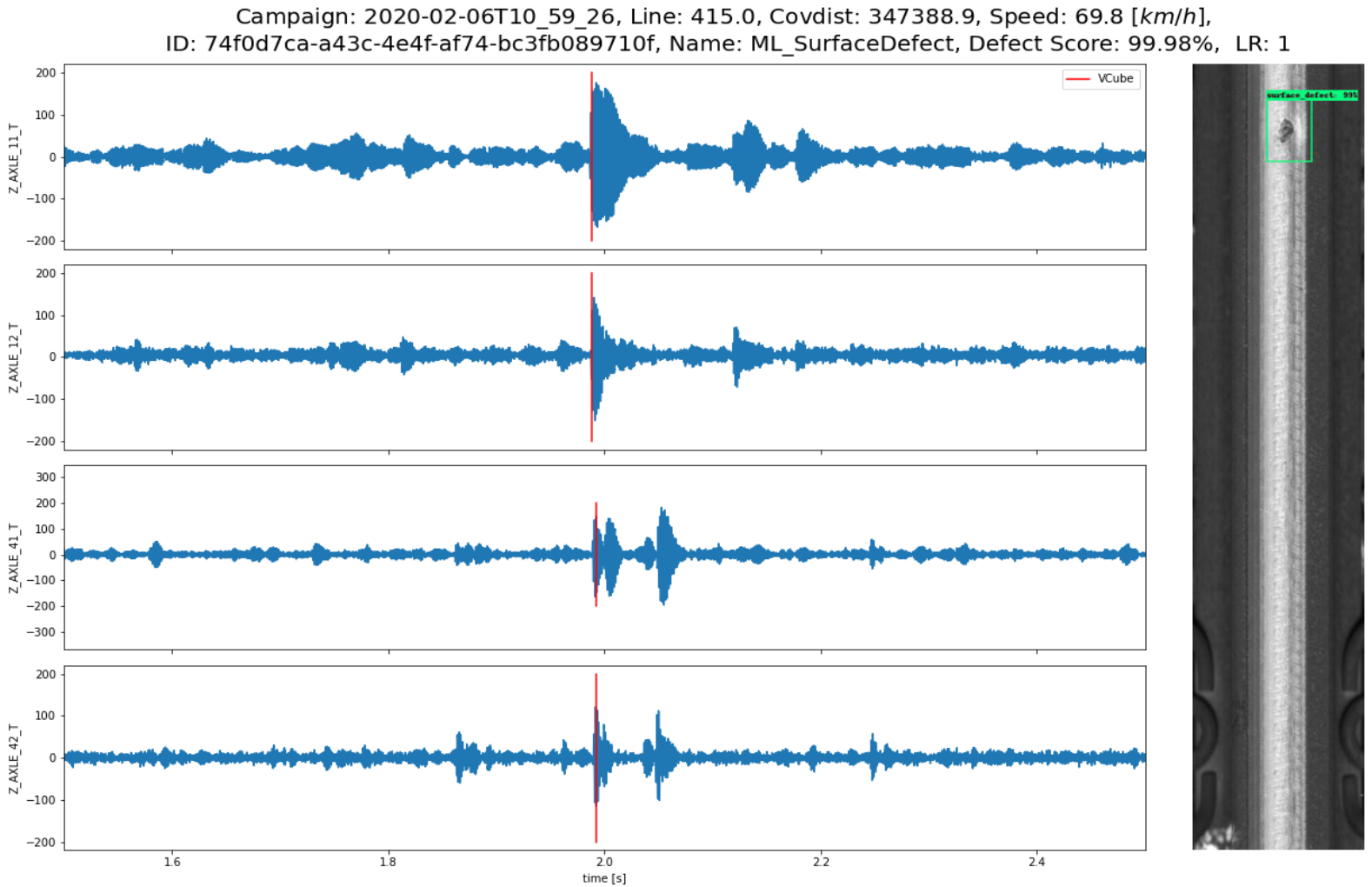
System Understanding and Management from On Board Monitoring (OBM)

The Longitudinal Level (LL) can be used as a proxy of the condition of the track (irregularity), for which the corresponding maintenance action is tamping.



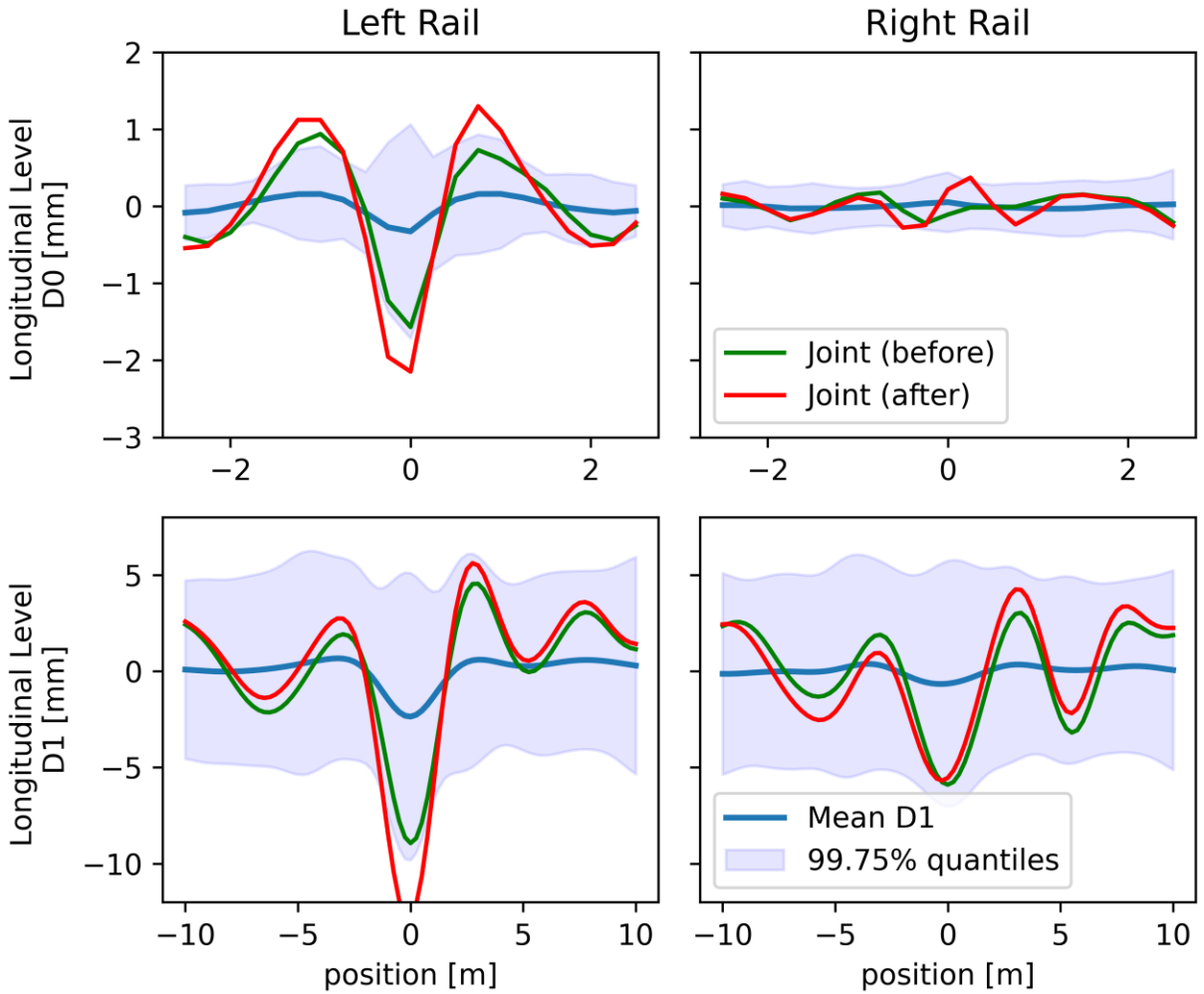
OBM-based Fault/Event Detection and Characterization

OBM accelerations can complement the Automated (image-based) Track Inspection with acceleration-based detection and classification of short wave (D0) effects.

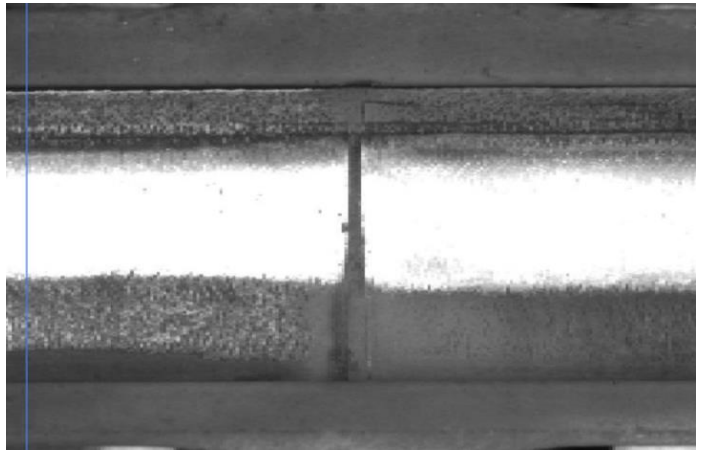


Damage Detection on Critical Components (joints)

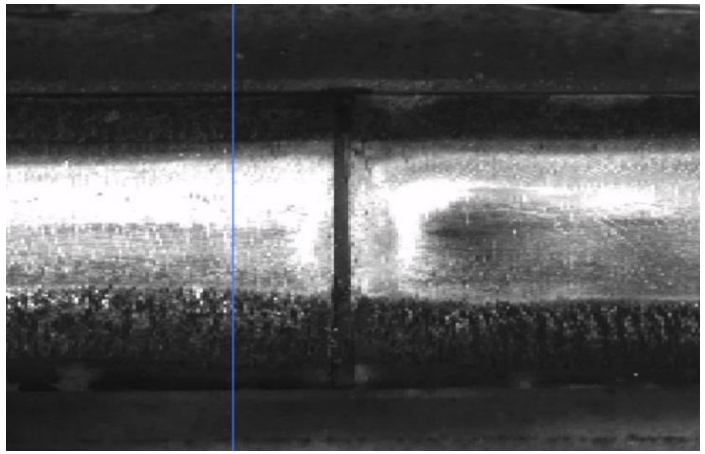
Outlier detection on Longitudinal Level from OBM-ABA (D0)



October 20

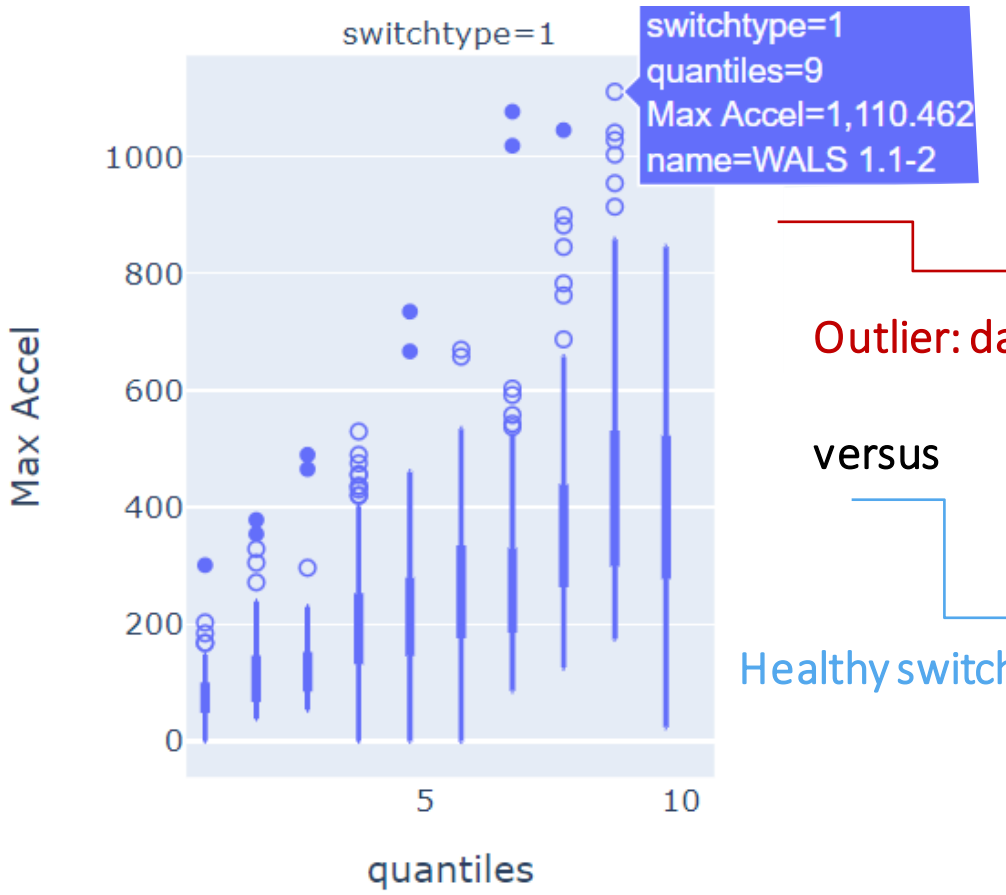


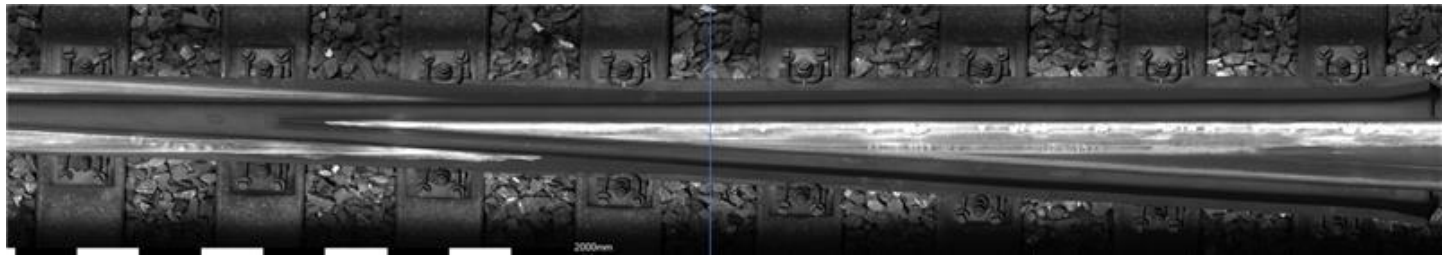
January 21



Damage Detection on Critical Components (Switches)

Outlier detection on Axle-Box-Acceleration Amplitudes



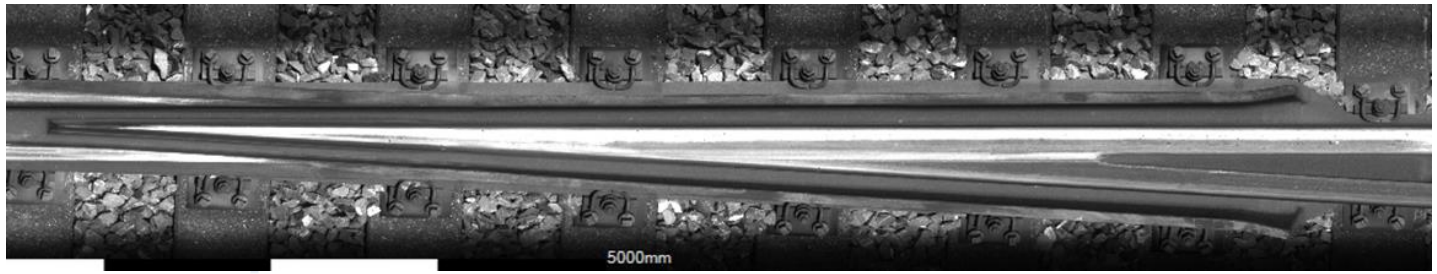


Outlier: damaged

WALS 1: 111g lateral, 54g vertical, ~120km/h

versus

Healthy switch

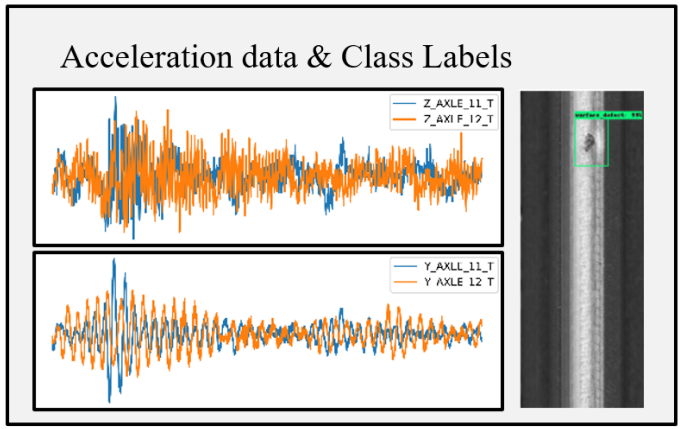


WALS 2: 19g lateral, 17g vertical, ~120 km/h

**An inspection on switch WALS 1 has shown that a colision between the guard rail and the wheel caused the axle to impact the frog, resulting in surface damages and squats on this component.*

Acceleration based event classification using machine learning

- Surface Defects
- Weld
- Insulated Joint
- No Defect

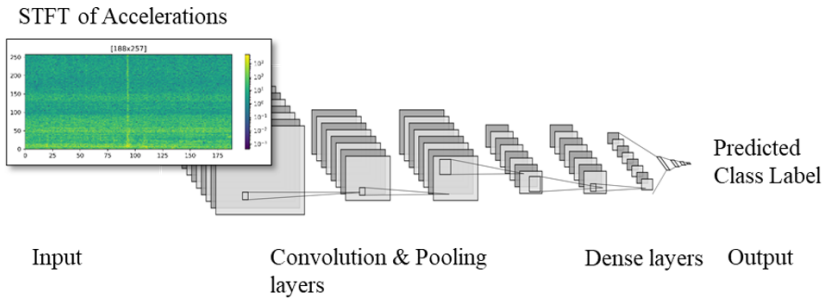


Extraction of Indicators
- Longitudinal Level D0, D1, D2
- DWT Coefficients

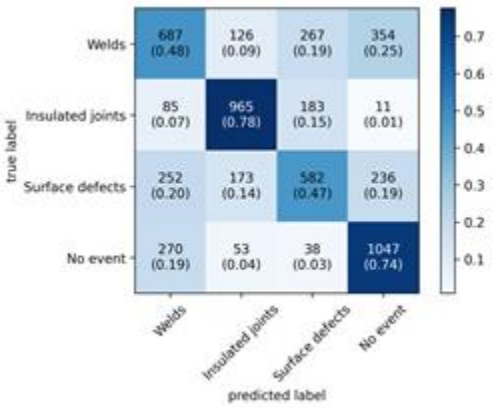
Computation of Basic Features
- Statistical Parameters
- Energy & Entropy

Features Selection
- All Features or Empirical selection
- PCA,…

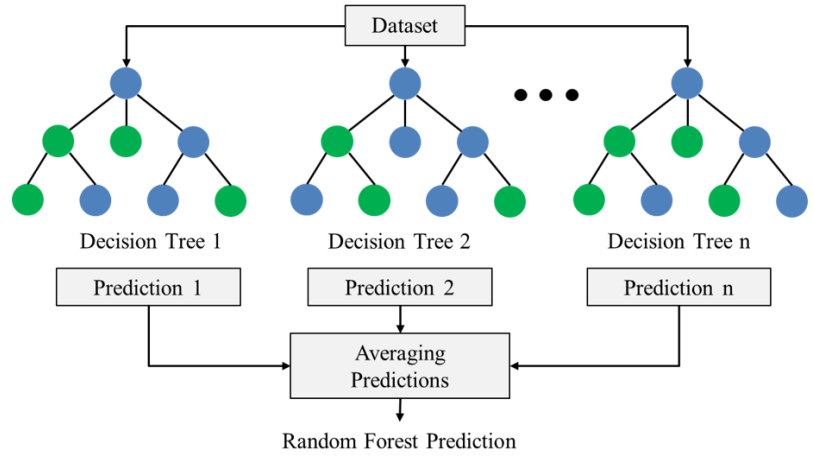
Convolutional Neural Network for CWT, STFT, DWT of ABA



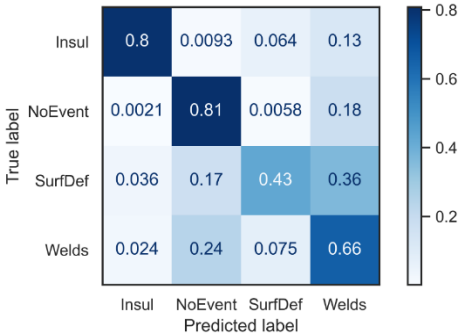
CNN-model on speed normalized STFT



Random Forest Model Classification for different features sets



Random Forest Classifier

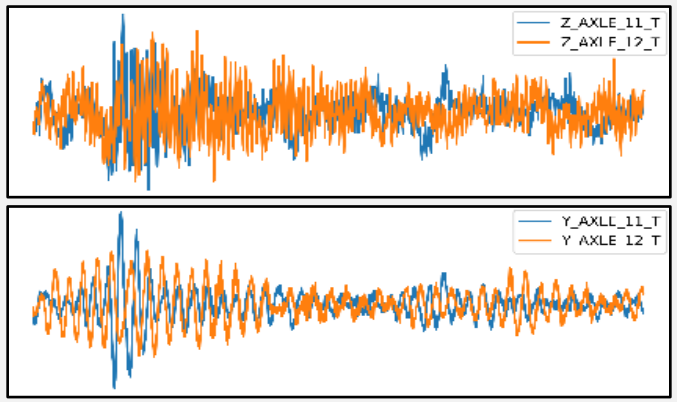


(b) Normalized

Normalized confusion matrix
Train score: 0.94
Test score: 0.71

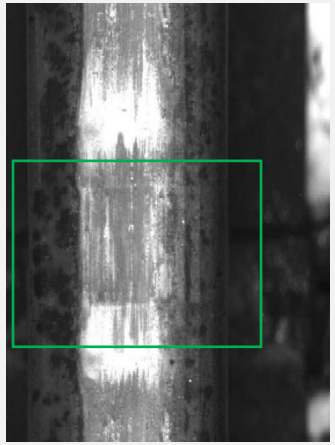
Data-driven assessment of weld condition

Acceleration data on weld from OBM or DFZ



Database of welds
- UUID
- Track position
- Side (left /right)

Observation DB of welds
- UUID
- Campaign
- Image

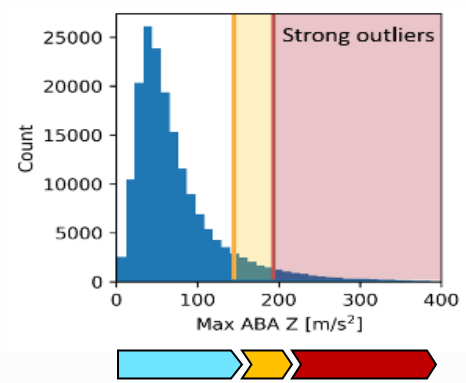


Extraction of indicators
- Longitudinal level D0...
- DWT coefficients

Feature computation
- Statistical parameters
- Energy & entropy

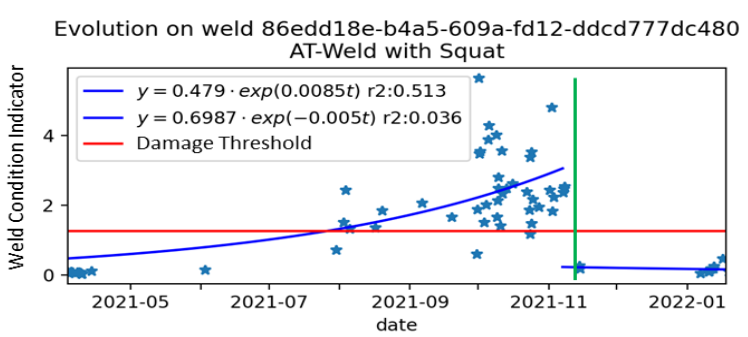
Features selection
- All features or empirical selection
- PCA,…

Extreme Value Analysis & Outlier Identification



Expert Evaluation
- Damage type, urgency,…

Regression & Prediction



Evolution in time using OBM data for early damage detection on welds

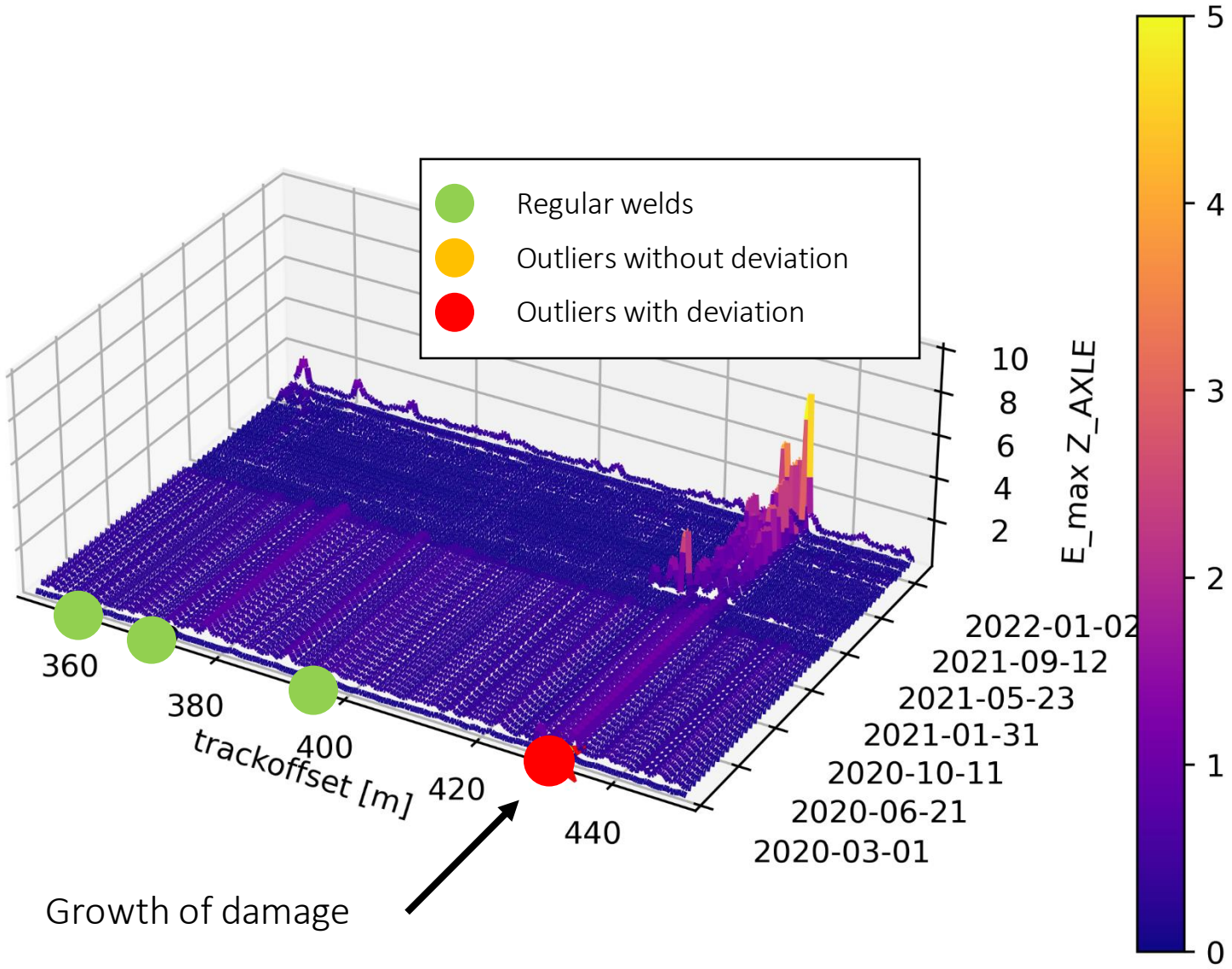
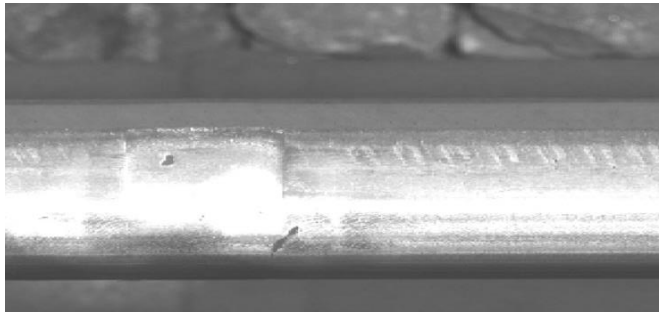
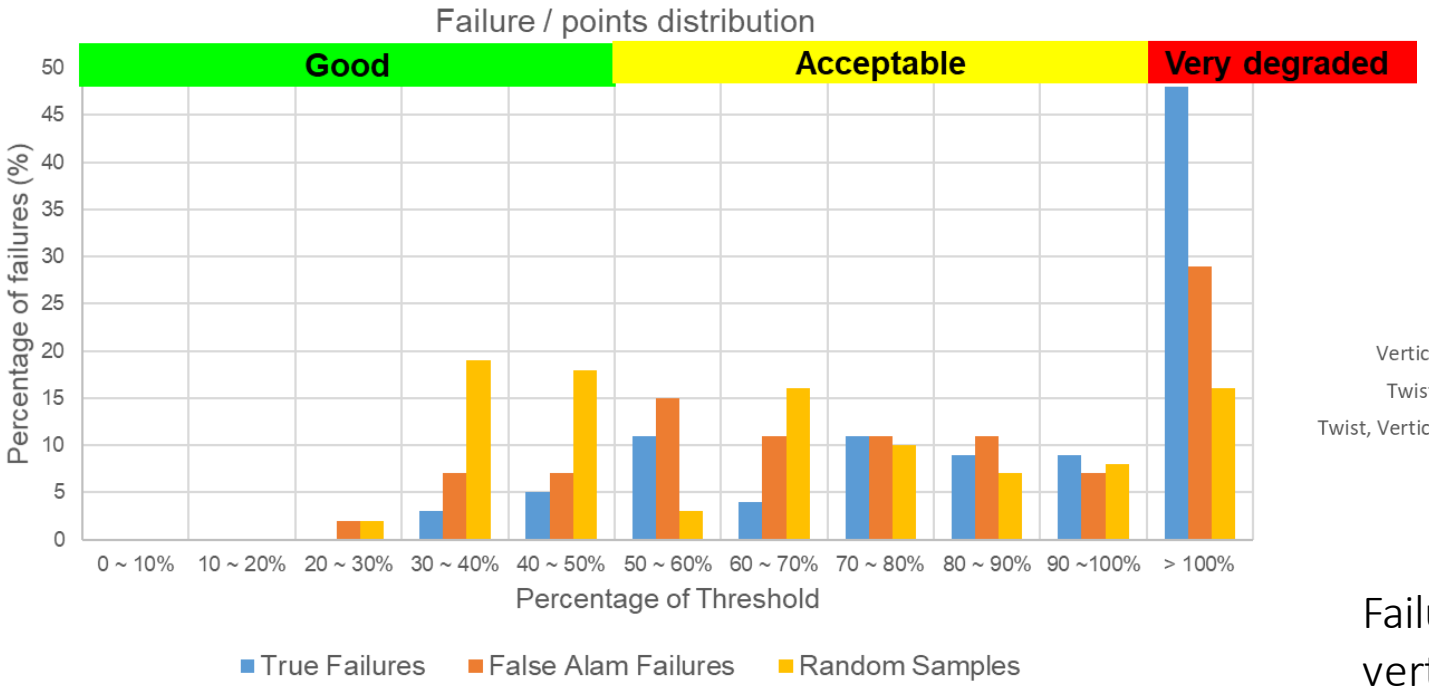


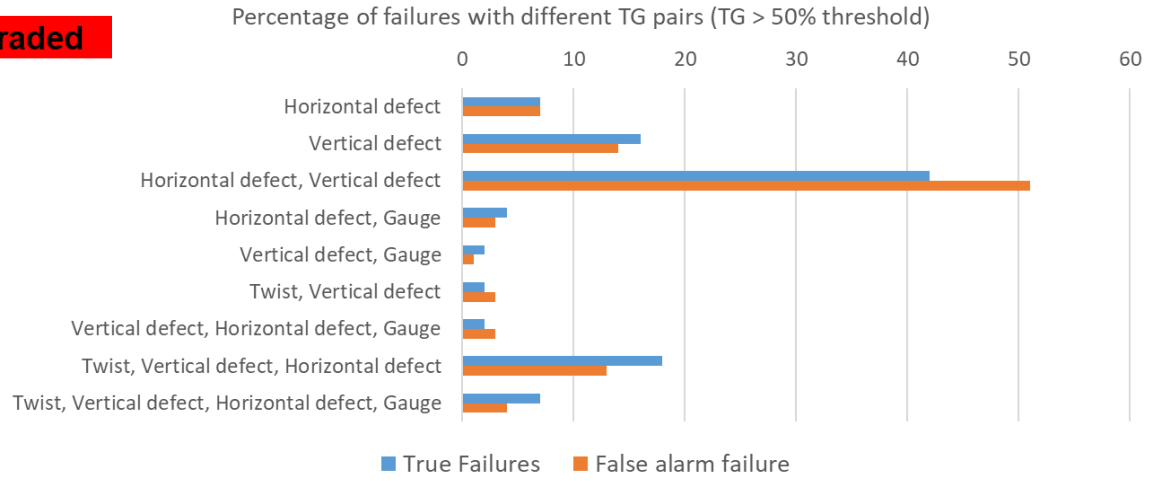
Illustration of the corresponding weld



Pillar II: Analyze the relation between Track status and Driver Response Failures based on collected inspection and failure data

Strong connection between track status and failures

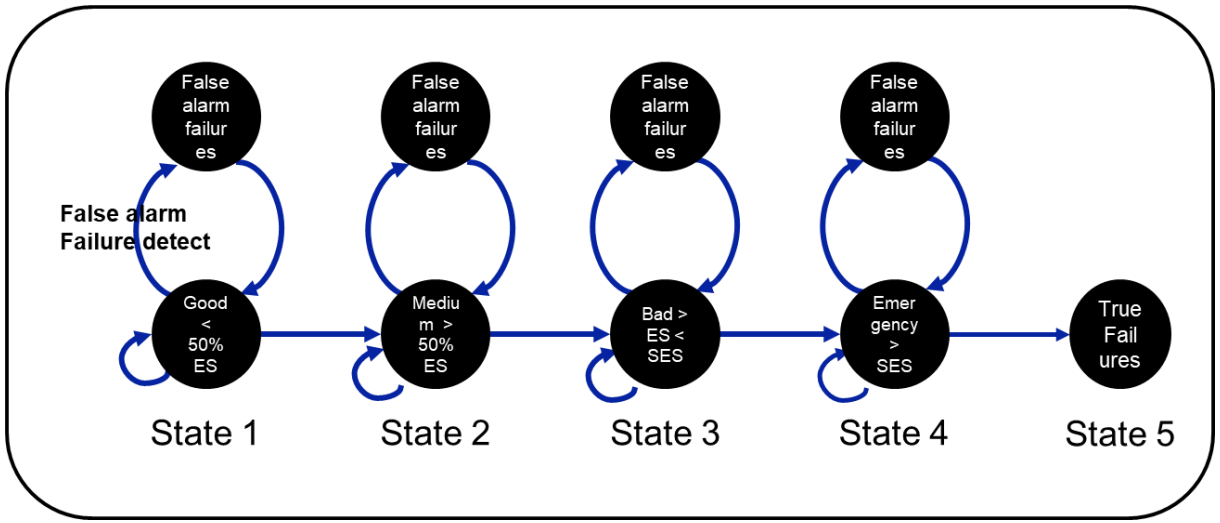


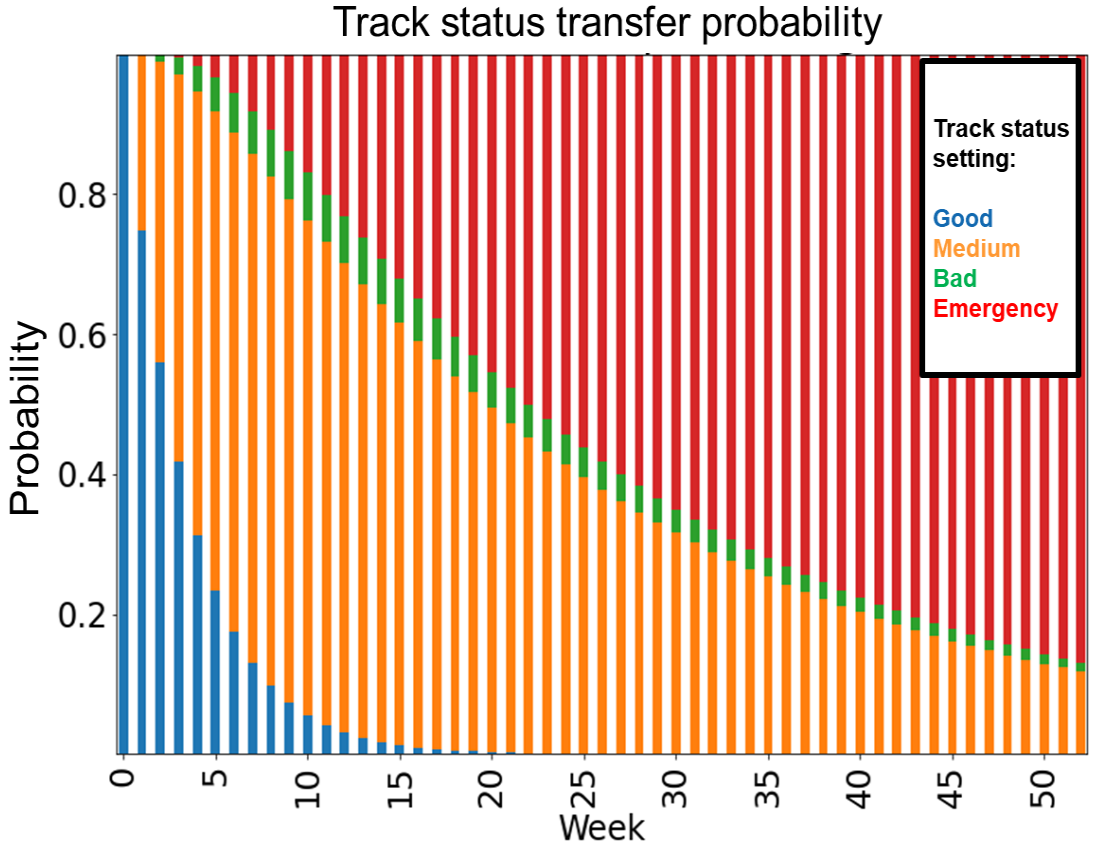


Failures are more likely to be triggered by co-existence of vertical and horizontal defects

Track status and failure prediction model via Markov

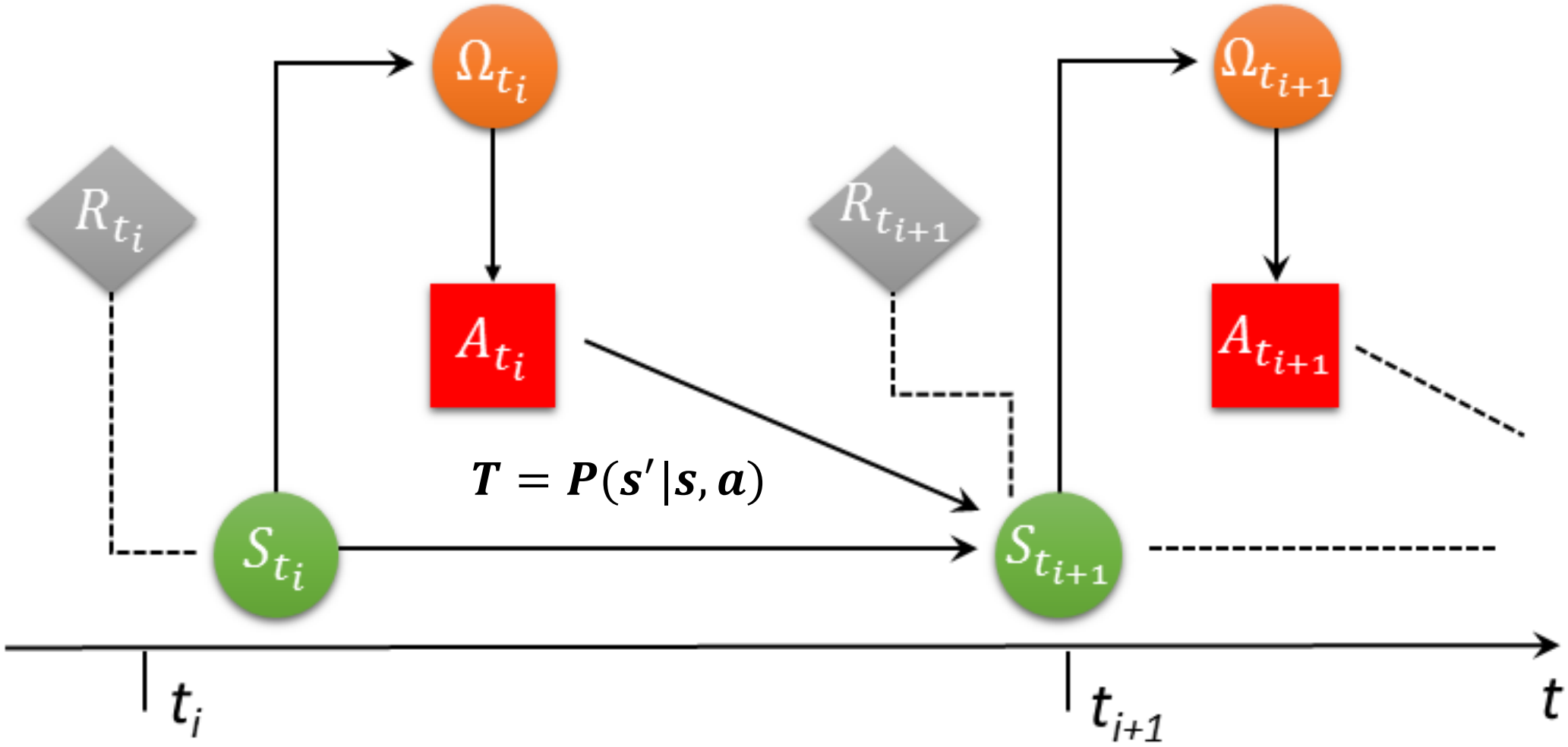
The OBM data can be used for developing track status and failure prediction models.
Markov Models are applied for quantifying the risks of the decisions for maintenance planning





Sequential decision process with alternating actions and inspections

e.g. Markov Decision Process



Goals / Value for the SBB

- Fully automated end-to-end processing of raw on board acceleration measurements into consolidated indicators (TQIs), which are transferrable to the swissTAMP database
- Deliver a low-cost in-service OBM solution, complemented by higher-end measurements by diagnostic vehicles for robust predictive & diagnostic capabilities. Capitalize on fusion of diverse measurements (Vcube: image-based and VTIMS: acceleration-based)
- Infer & understand the progression of OBM-based indicators over time in infrastructure assets (e.g. joints, welds, switches, surface defects) and be able to set thresholds for intervention / inspection
- Decrease the amount of time SBB inspectors spend on the tracks to improve their safety and to point out the top criteria of the infrastructure assets.
- Generate a better system understanding.

ETH zürich

We welcome questions/comments/collaboration:

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