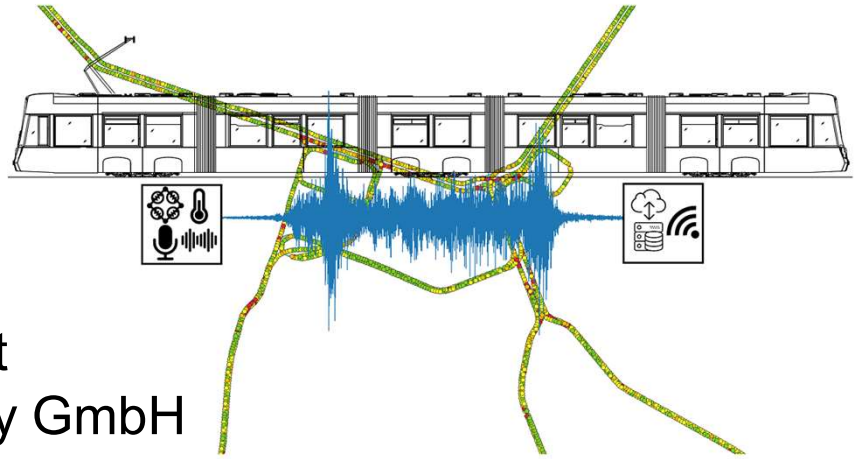
Vibro-Acoustic Inspection of Vienna's Tram Network



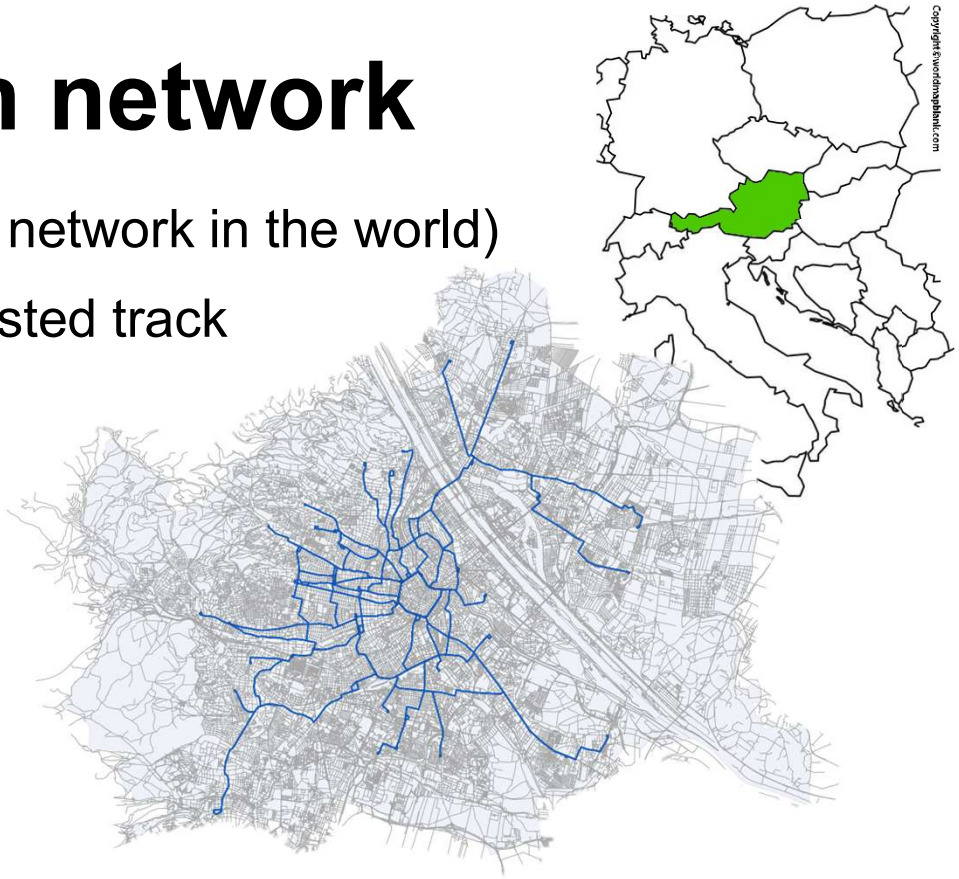
KAROLINE ALTEN
Scientist
Center for Low-Emission Transport
AIT Austrian Institute of Technology GmbH

Outline

1. Vienna's tram network
2. Information from onboard monitoring
3. Vibro-acoustic features for fault detection
4. Summary of current evaluation tools
5. Outlook on future research

1. Vienna's tram network

- 220 km of track (6th largest network in the world)
- 91% grooved rail, 9% ballasted track
- 1076 stops, 480 vehicles, 1100 turnouts
- 2019:
  304.8 mil. passengers,
  travelling 22.9 mil. km

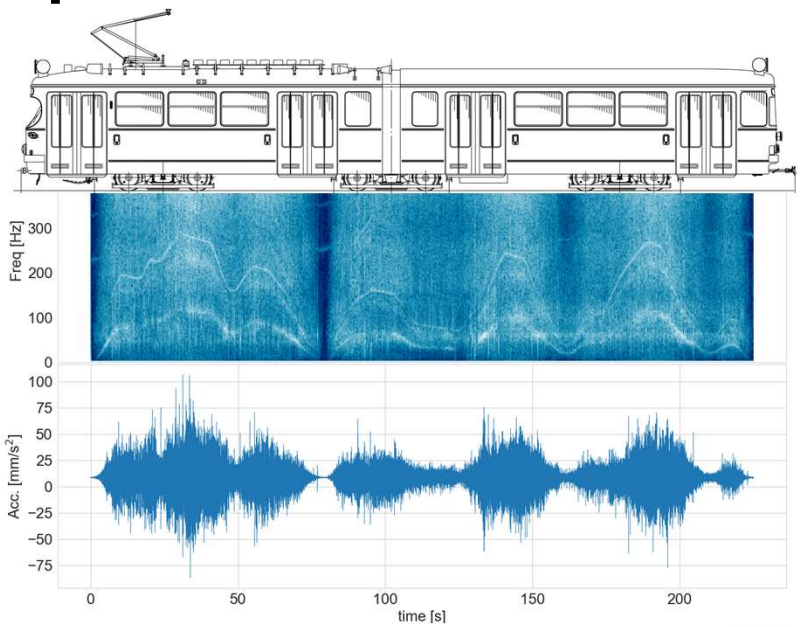


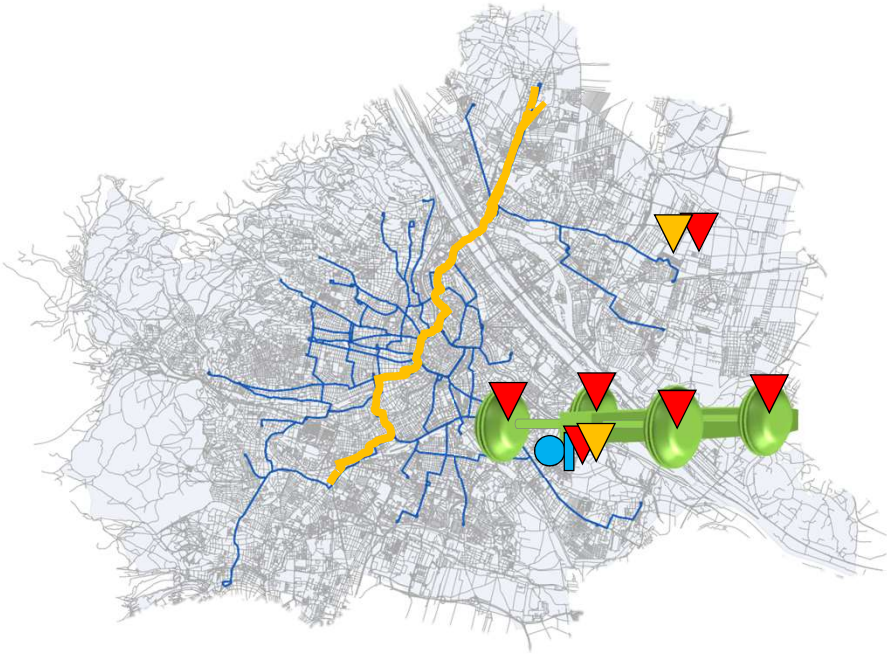
1. Vienna’s tram network

Inspection vehicle

1. Vienna's tram network

Inspection vehicle





2. Information from onboard monitoring

Prerequisites

- Aggregation of data into bins
- Data stored in PostgreSQL
- Correlation models for level correction
- Auxiliary information needed

2. Information from onboard monitoring

Curve squeal

Corrugation

Turnouts and crossings

3. Vibro-acoustic features

3.1 Curve squeal

- Tonal emission in tight curves
- Occurrence depends on wheelbase of bogie
- Slip: difference in distance between inner and outer wheel when wheels are not independent
- Bins: 0.5 sec

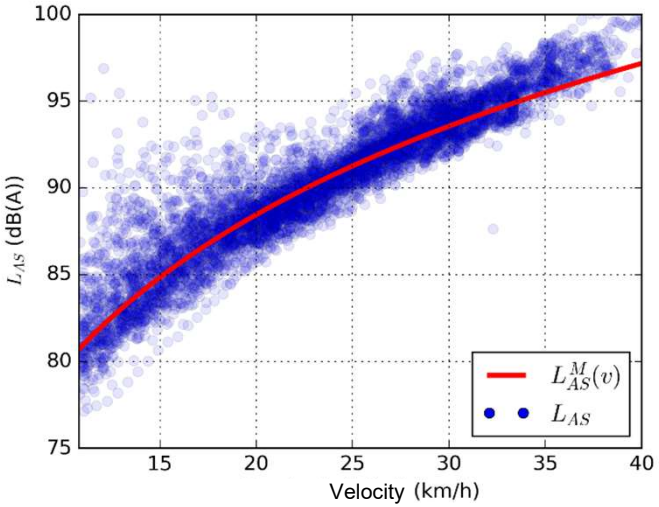
3. Vibro-acoustic features

3.1 Curve squeal: Detection

Step 1: Dimensionality reduction

Features selected through logit regression:

- Welch-Periodograms, 20 Hz resolution
- Velocity
- Curvature
- Relative sound level

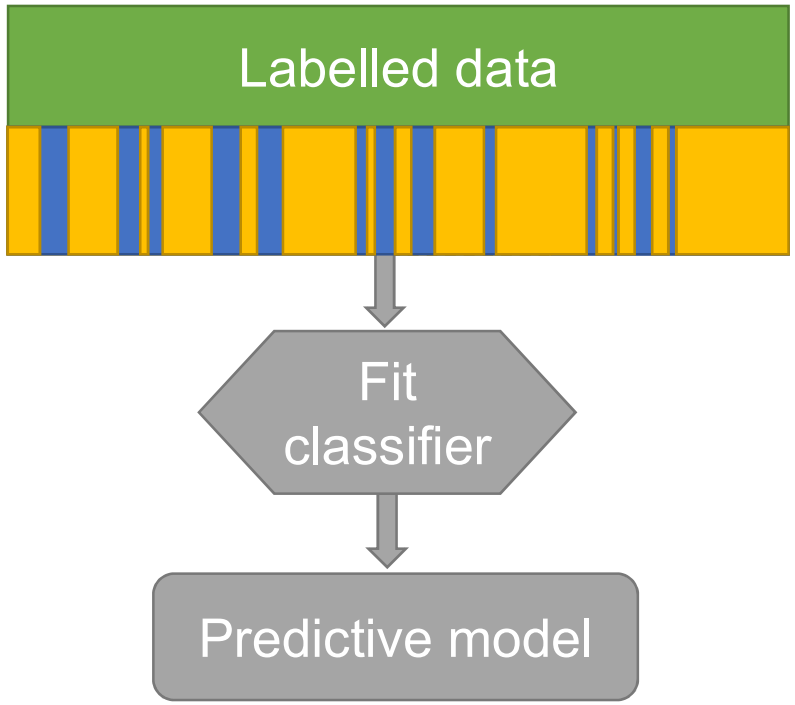


3. Vibro-acoustic features

3.1 Curve squeal: Detection

Step 2: Classification of curve squeal

Binary decision through LDA



3. Vibro-acoustic features

3.2 Corrugation

- Periodic deformation (5-15 cm)
- Extending across tens of metres
- Occurrence in braking/acceleration sections (stops), curves
- Bins: 5m

3. Vibro-acoustic features

3.2 Corrugation: Detection and Classification

Features:

- Standard deviation
- $L_{acc,F}$ and $L_{acc,F,i}$ (3.15 – 315 Hz)
- $L_{acc,F,vBP}$ (variable bandpass)
- Intensity ratio ($L_{acc,F,vBP}/L_{acc,F}$)
- Delta to expected value per bin
- Correlation to neighbouring bins
- Autocorrelation within bins

3. Vibro-acoustic features

3.2 Corrugation: Detection and Classification

$L_{acc,F,vBP}$ (variable bandpass)

$$f_{min} = \frac{v}{0.15}$$

$$f_{max} = \frac{v}{0.05}$$

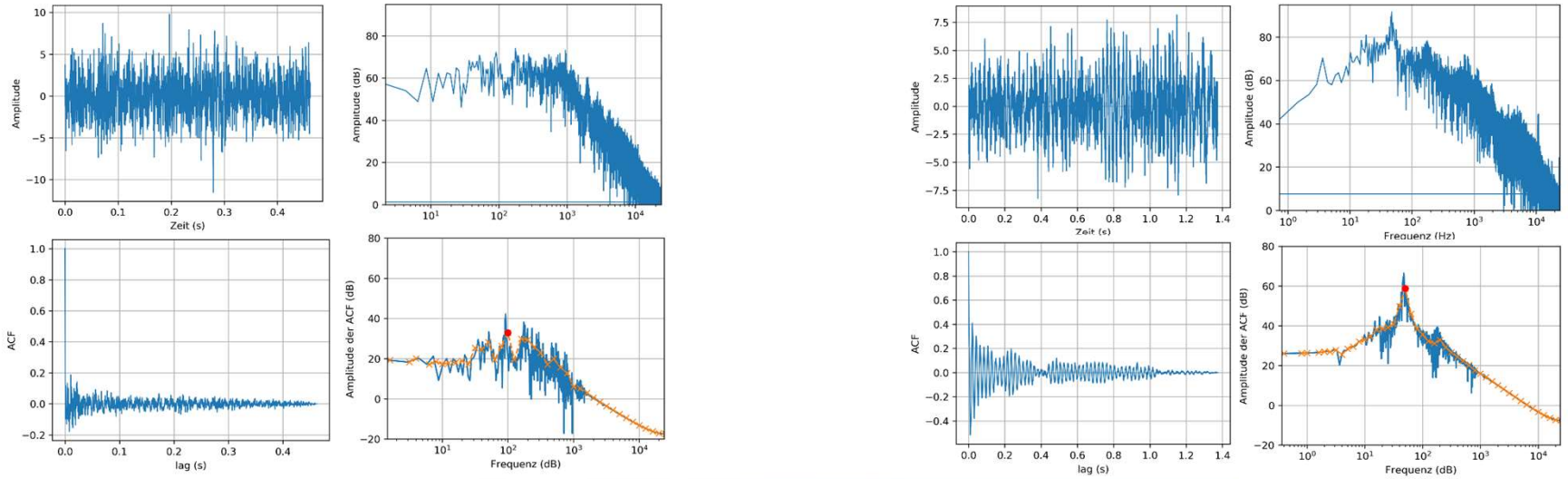
3. Vibro-acoustic features

3.2 Corrugation: Detection and Classification

Class 1

Autocorrelation within bin

Class 7



3. Vibro-acoustic features

3.2 Corrugation: Detection and Classification

2 approaches investigated:

- Classification algorithms
- Regression models

3. Vibro-acoustic features

3.2 Corrugation: Detection and Classification

2 approaches investigated:

- Classification algorithms
- Regression models

Problems

- Imbalanced datasets
- Too few independent bins
- Reasonable no. of features?
- Other rail head irregularities hard to differentiate
- Inaccuracies in labelled bin position

3. Vibro-acoustic features

3.2 Corrugation: Detection and Classification

2 approaches investigated:

- Classification algorithms
- Regression models

Solutions

- Fewer classes
- Exclude redundant sensors
- SV regression

3. Vibro-acoustic features

3.3 Turnouts and Crossings

Switch structure on grooved rails

Only regarding mechanical defects in wheel-rail contact area

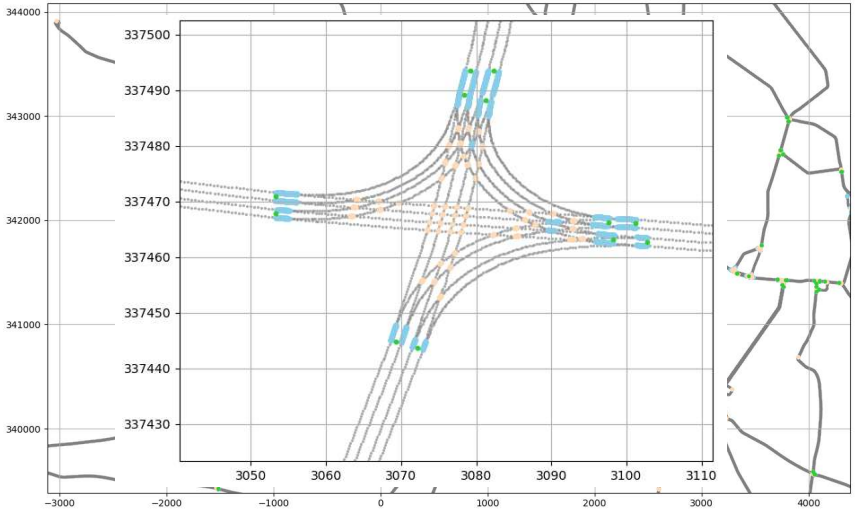
3. Vibro-acoustic features

3.3 Turnouts and Crossings: Defect detection

Challenges:

- Ramped crossings
- Unique geometries
- Closely spaced crossings

→ Define frog clusters



3. Vibro-acoustic features

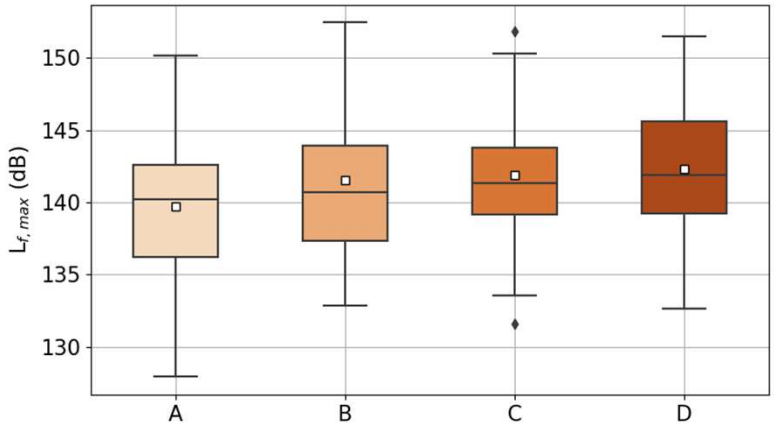
3.3 Turnouts and Crossings: Defect detection

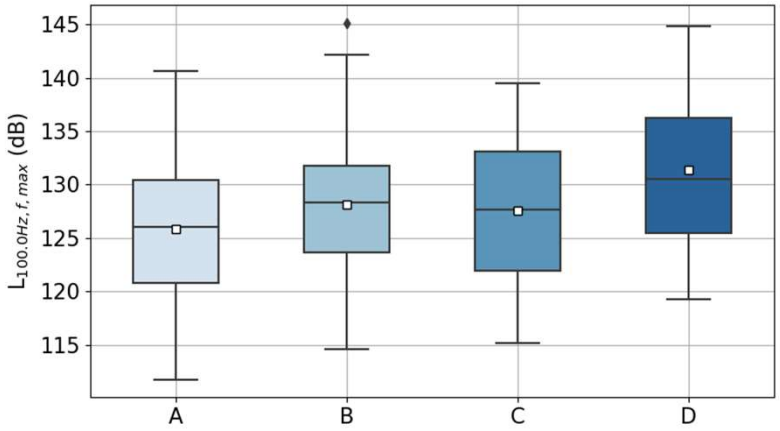
Features currently investigated:

- Peak amplitudes (sound and vibration)
- Statistical moments
- Third-octave band levels and percentiles thereof
- No. of peaks
- Psycho-acoustic parameters

3. Vibro-acoustic features

3.3 Turnouts and Crossings: Defect detection





4. Summary of evaluation tools

- Network maps with corrugation values, squeal locations and relative loudness of turnouts
- Allow pre-emptive action against complaints about high immission levels in inner city areas and prioritize rail sections for maintenance

Work in progress

WIENER LINIEN

© Wiener Linien/Johannes Zinner

© Wiener Linien/Manfred Helmer

Work in progress

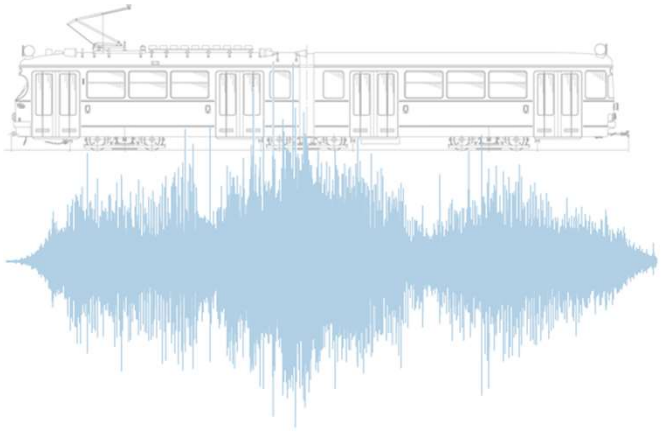
5. Outlook

- **Transferability to other fleets**: Usefulness for other light rail networks
- Investigate **long-term stability** of onboard sensors
- Check transferability between onboard **emission and immission** (“noise maps”)

Thank you

KAROLINE ALTEN
Scientist
Center for Low-Emission Transport
Transportation Infrastructure Technologies

AIT Austrian Institute of Technology GmbH
Giefinggasse 2 | 1210 Vienna | Austria
T +43 50550-6690 | M +43 664 235 1879 | F +43 50550-6439
karoline.alten@ait.ac.at | http://www.ait.ac.at



The research presented here is funded by the Austrian Research Promotion Agency

FFG Forschung wirkt.