In-*SE*rvice diagnostics of the cate*N*ary/pan*T*ograph and wheelset axle systems through *IN*t*EL*ligent algorithms: ***SENTINEL***

Ehsan Naghizadeh[1], Hao Dong[1], Paolo Tiso[1] , Olga Fink[2] , Eleni Chatzi[1]
[1]ETH Zurich; [2]EPFL

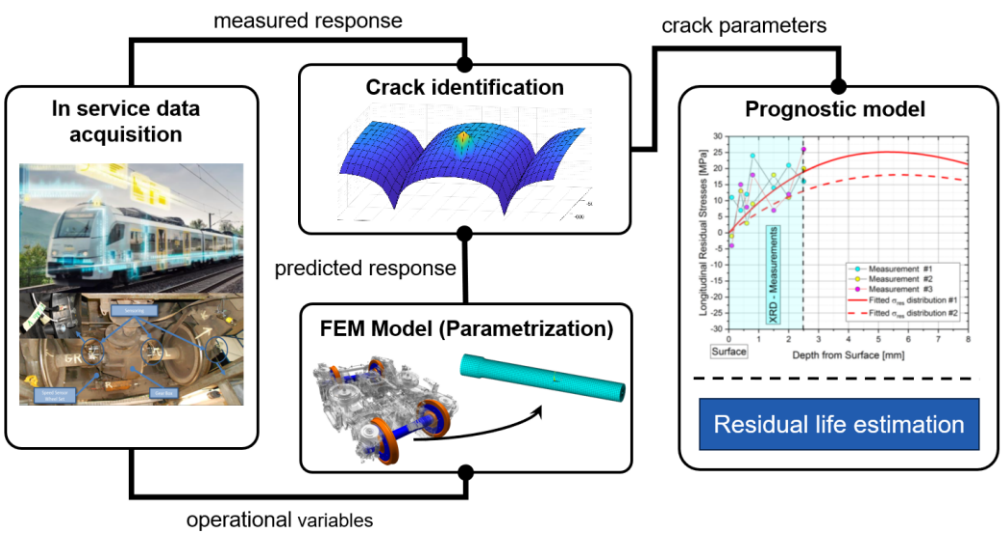
1 Introduction

Structural health monitoring of critical components of trains is key for safety and cost efficiency.

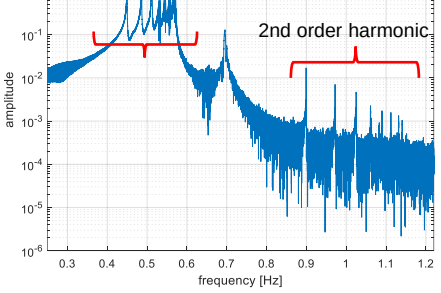
The goal of this project is to provide effective in-service health monitoring techniques to allow for early detection, localization and classification of defects in an effort to significantly reduce the down time and at the same time increase safety.

The wheelset axle and the catenary-pantograph are the two critical components taken into consideration the two pillars of this project.

2 Wheelset Axle

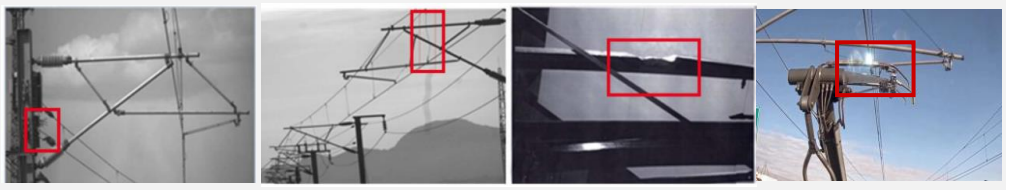


- Linear vibrational measures i.e., natural frequencies are not sensitive to early stages cracks.
- The nonlinear breathing effect of cracks allows for extraction of damage sensitive features.
- We introduce Higher Order Transmissibility based on Higher Order FRFs as a crack detection feature.
- We derive an approximative formulation which speeds up solution of the (inverse) damage identification problem by avoiding nonlinear analyses.

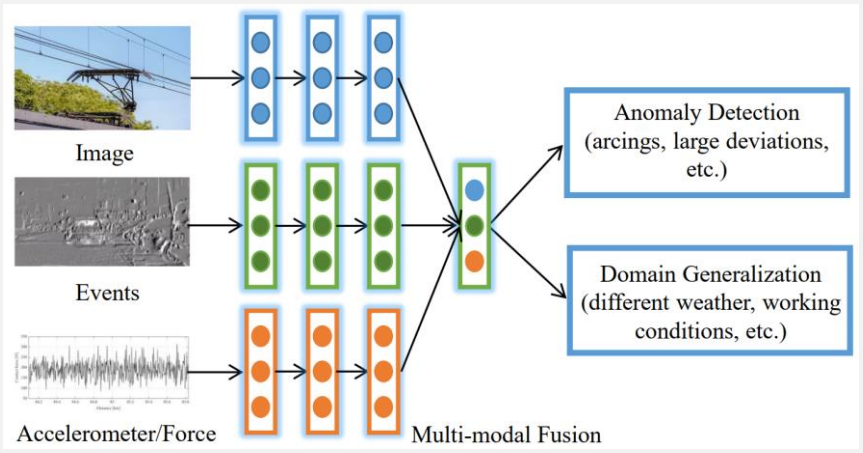


- ✓ FEM modeling of the shaft with Nonlinear Breathing Crack model.
- ✓ Component Mode Synthesis (Linear ROM).
- ✓ Parametrization of the FEM with respect to crack.
- ✓ Higher Order Transmissibility as crack identification feature.
- ✓ Sensitivity of Higher Order Transmissibility to crack parameters in 3D
- – Inverse problem setup and Crack Parameter estimation.
- – Crack propagation and fatigue failure.
- ○ SHM scheme integrated with the derived efficient parametric ROM of the shaft.

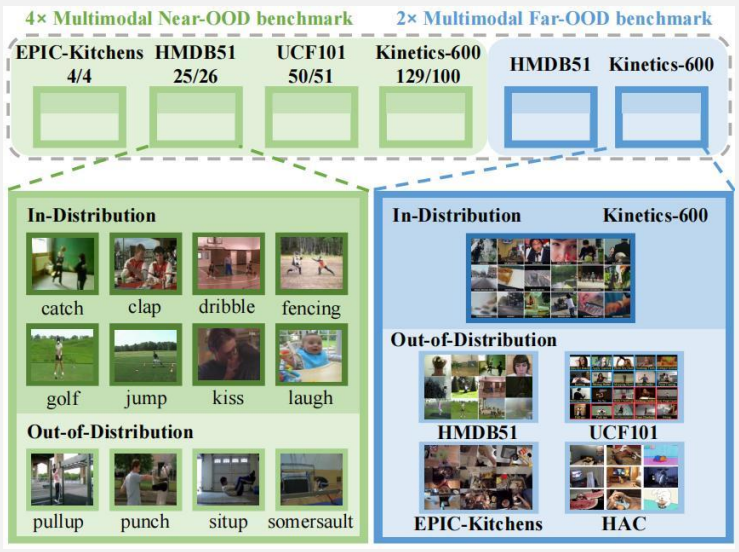
3 Catenary-Pantograph



Different types of anomalies



Pipeline for anomaly detection and domain generalization with different modalities



Multimodal Out-of-Distribution Detection

5 Conclusion and expected impact

- Consistent spatially and temporally dense monitoring of the condition of the catenary line.
- Improved availability of the infrastructure and reduced risk of line teardown and other power line maintenance.
- Robust in-service crack detection scheme based on nonlinear behavior of breathing crack.
- Significant increase in the efficiency of trains by eliminating the inspection down time and enhancing safety.

References

1. Ruff, Lukas, et al. "Deep one-class classification." International Conference on Machine Learning. 2018.
2. Wang, Jindong, et al. "Generalizing to unseen domains: A survey on domain generalization." IEEE Transactions on Knowledge and Data Engineering. 2022.
3. Lu Z, Li F, Cao S, Yuan R, Lv Y. Crack Localization in Operating Rotors Based on Multivariate Higher Order Dynamic Mode Decomposition. *Sensors*. 2022

Partner: