Railway Ballast Health Monitoring Using Spectral Methods

Type of project	MSc project
ECTS	35
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Collaboration agreement	Already in place
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Project Description

Railway networks heavily rely on the correct functioning of switches and crossings (S&Cs) to properly and safely route the train traffic. The dynamic response of an S&C during a train passage heavily depends on the structural health condition of the different components the infrastructure consists of, namely the rail, the sleeper, the sleeper pad, the ballast and the sub-ballast layers. To guarantee the dependability and safety of the infrastructure timely maintenance plays a central role. Currently the maintenance of the S&Cs is reactive, i.e. based on regular manned inspections of the quality of the infrastructure. This approach has two clear drawbacks: unevenness of the decisions and sole access to information available at the surface of the infrastructure.

The quality of the ballast and sub-ballast has a great impact into the stiffness of the overall structure and hence into the dynamic response of the infrastructure during train passage. It is indeed quite common that diminished performance at the surface level is the results of long-term deterioration processes happening underground. The project envisages to devise algorithms for health monitoring of the ballast layer based on spectral methods, i.e. methods relying on the frequency analysis of relevant signals such as accelerations and/or displacements measured at the railway or sleeper levels. Methods of interests could be Fourier Transform, Short-time Fourier Transform, Wavelet Transform, Higher Order Spectra Analysis, etc.

Project Objectives

The following objectives are envisaged to be achieved towards the fulfilment of the project scope:

- Determine the state-of-the-art of structure health monitoring based on frequency domain methods, with particular focus on railway infrastructure. Analyze advantages and disadvantages of the approaches available in literature with respect to the project scope. Propose possible methodologies applicable in the project

- Analyze in the frequency domain simulated data from high-fidelity multibody simulations of wheel-rail interaction showcasing both healthy and deteriorated ballast conditions. Identify signatures that could be used for health monitoring of the ballast.
- Analyze in the frequency domain full-scale motion data from an instrumented S&C located at Tommerup station (Funen) and compare the findings with those achieved based on simulated data.
- Devise ballast condition monitoring algorithms based on frequency domain methods and evaluate their detection capabilities against the simulated data. In the performance evaluation focus should be placed on the probability of false alarms, probability of detection and the smallest detectable deterioration.
- Evaluate the developed condition monitoring system on the full-scale motion data and compare the obtained results against the theoretical expectations.

Resources

Simulated data of the wheel-rail interaction from high-fidelity multibody simulation software will be available as well as large full-scale motion data collected at the instrumented S&C at Tommerup station.

Literature

- Kay, S. M., “Fundamentals of Statistical Signal Processing: Detection Theory”, 1998, Prentice Hall
- Percival, D. B., Walden, A. T., “Wavelet Methods for Time Series Analysis”, 2006, Cambridge University Press
- Mallat, S., “A Wavelet Tour to Signal Processing”, 2008, Academic Press
- Relevant publications