University of Applied Sciences and Arts Northwestern Switzerland
School of Architecture, Civil Engineering and Geomatics

MASTER OF SCIENCE
IN ENGINEERING

Analysis of ground penetrating radar (GPR) profiles for the detection of specific ground conditions

GPR is a non-invasive technique used to visualize subsurface features and understand the composition and structure of the ground. It involves emitting electromagnetic waves into the subsoil and recording reflections. Distinguishing between different materials is a challenge in interpreting GPR data, but it is crucial for characterizing subsurface conditions. This study focuses on detecting clay in the ballast under tracks, which can significantly compromise load-bearing capacity and overall track stability. Additionally, the presence of clay reduces the ballast's elasticity, leading to increased vibrations. This impacts passenger comfort and contributes to increased wear and tear on the rails and rolling stock.

Georadar

The operation of a georadar is based on the propagation of electromagnetic waves in media with different dielectric constants. If the difference in dielectric constant between two media is sufficiently large, the signal emitted by the transmitter (T) is reflected and detected by the receiver (R). By measuring the time, it takes for the signal (S) to propagate, and the amplitude of the received signal, different objects or materials can be detected and located (Fig. 1).

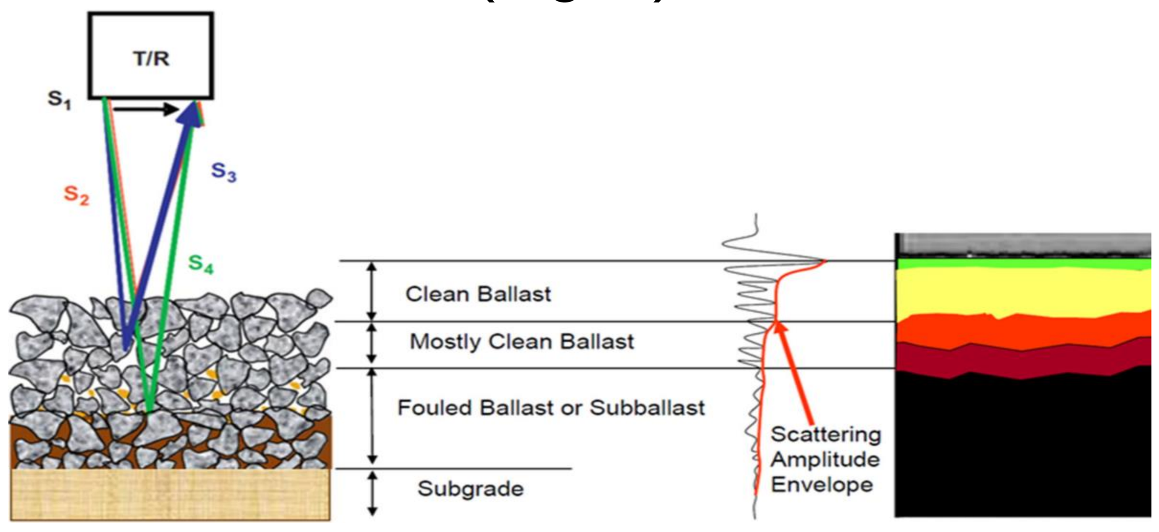

Fig. 1: Principle of GPR detection for contaminated ballast layers (Al-Qadi et al., 2010; Wang et al., 2022).

Target definition

The aim of this work is to process the signals of the GPR to detect layers in the subsoil. The focus is on the detection of clay layers in the ballast. A data processing workflow is developed, which enables the identification of clay impurities in the ballast with the use of GPR.

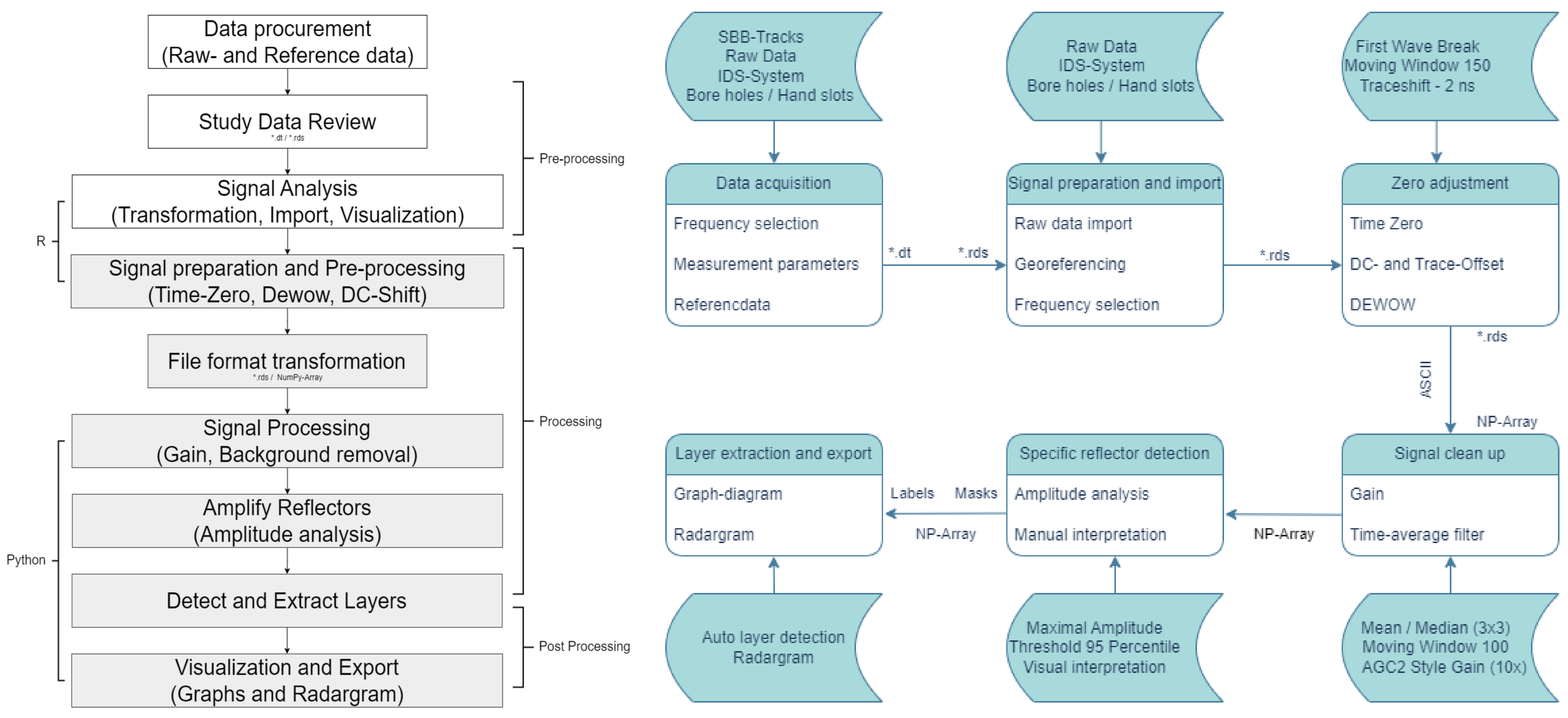

Fig. 2: Design Idea for the envisioned Workflow (l) and derived from this the implementation in a process flow chart (r).

Signal processing Workflow

Based on GPR raw data, the signal evaluation process (Fig. 2) could be defined, which follows the design idea from figure 2 (left). The library RGPR allows an easy import of raw data in sensor format and supports the evaluation with a wide range of available functions for pre-processing. These were also implemented in Python using rpy2 and other libraries. This allows the data to be displayed as amplitude and radargrams (Fig. 3). After the data preparation, it is further processed (cleansed) in order to carry out an amplitude analysis so that the layers sought after can be identified for extraction.

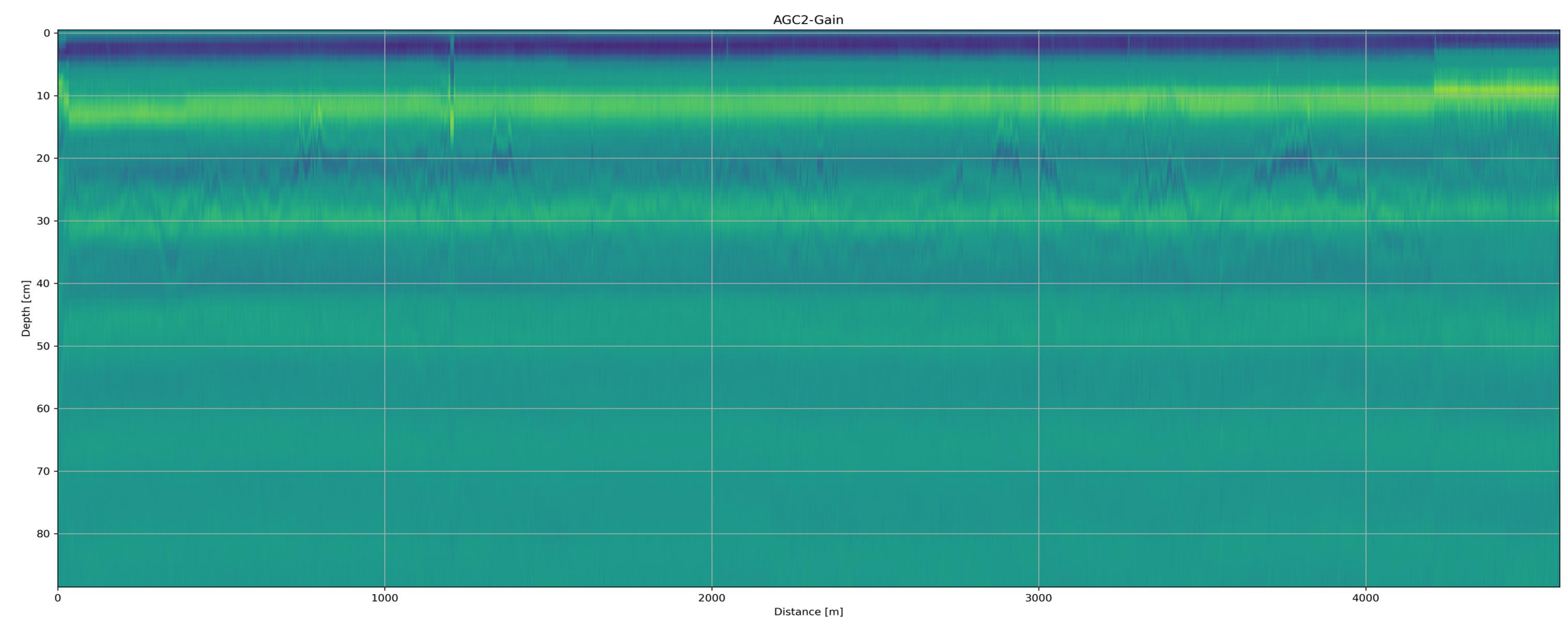

Fig. 3: All traces (depth / distance / amplitude values) of a GPR survey combined as a radargram.

Proof of Concept

The developed procedure was evaluated in the sense of a proof of concept. In other words, it was checked whether each step works correctly and leads to the expected results. By visually comparing the results of the signal processing with the data of a reference project, the success of this comparison can be determined by the degree of comparability and the ability to draw similar conclusions about the given subject. The reference chosen was a dataset previously processed and analysed (Gutiérrez, 2019). The reference data was then enriched with subsoil samples to allow a true validation of the results.

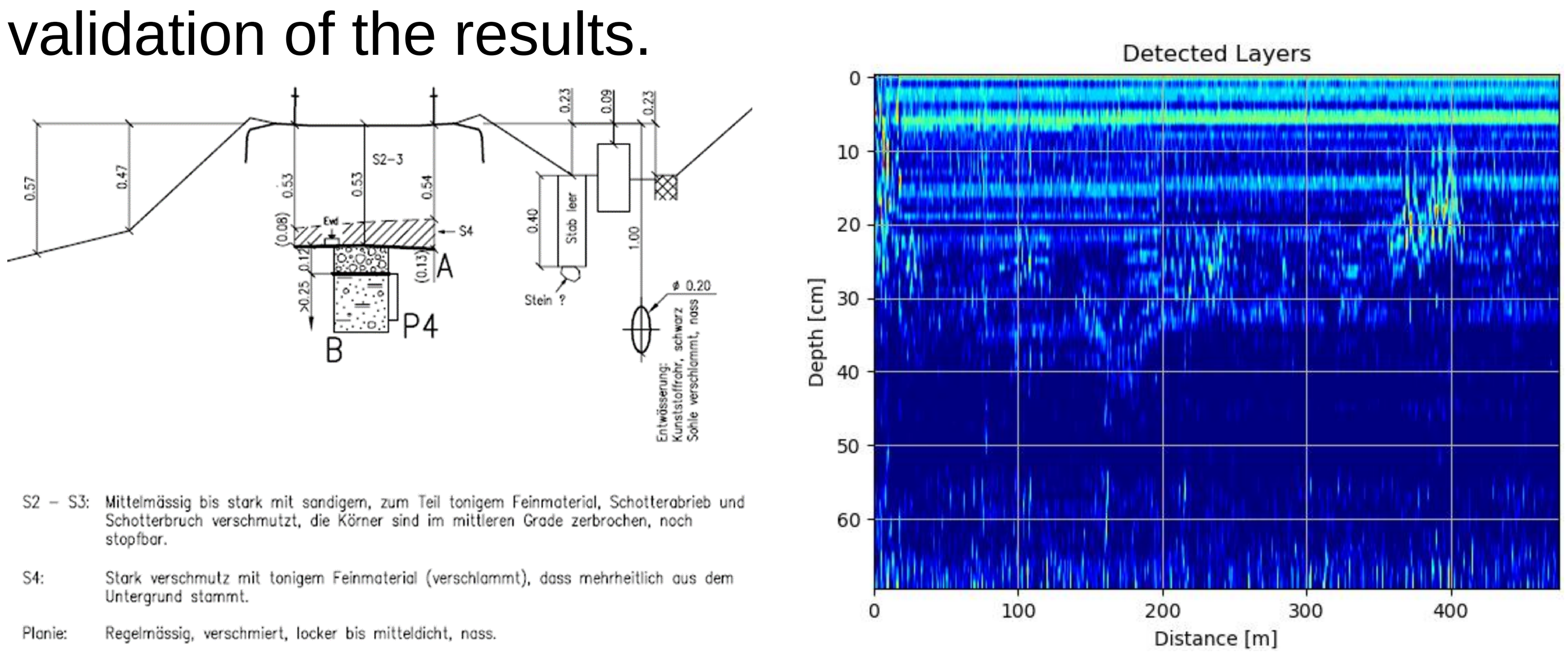

Fig. 4: Hand slit section (Würsch, 2019) from reference data set (l) used for validation of detection radargrams (r).

Conclusion

Except for automatic horizon detection and extraction, it was possible to demonstrate the functionality of all process steps in the sense of a proof-of-concept with the available data However, the validation of the results shows impressively that no useful results can be achieved without high-quality raw data. The goal of complete automation could not be achieved. In addition, further weaknesses were identified. Above all, the accessibility of the evaluation method and the achieved accuracy of detection still needs to be greatly improved.

References

Al-Qadi, I., Xie, W., & Roberts, R. (2010). Optimization of antenna configuration in multiple-frequency ground penetrating radar system for railroad substructure assessment. *NDT and E International*, *43*(1), 20–28.

Gutiérrez, I. (2019). Georadar-Messung: SBB (Issue Be254_2016-088_751, pp. 1–20). www.emp-winterthur.ch

Wang, S., Liu, G., Jing, G., Feng, Q., Liu, H., & Guo, Y. (2022). State-of-the-Art Review of Ground Penetrating Radar (GPR) Applications for Railway Ballast Inspection. *Sensors 2022, Vol. 22, Page 2450*, *22*(7), 2450.

Würsch, E. (2019). *SBB Sondagen: Schmerikon-Bollingen* (pp. 1–25). SBB AG.

Fabian Casutt
Supervisor: Dante Salvini / Denis Jordan, Expert: Edi Meier