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Texture Retrieval Approach for Interpreting GPR Data to Quantify Railroad Ballast Fouling

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Ballast is a main component of railroad structure. Clean ballast comprises of relatively large aggregates that forms big air voids within the ballast system. However, over time, the air voids may get filled with fine materials due to ballast breakdown and infiltration of small particles. This phenomenon is called fouling. Fouling is detrimental to the ballast structure's integrity and its drainage capacity. Fouling level should be monitored to optimize railroad maintenance. Traditional approach to assess fouling condition is through visual inspection and sample drilling. While visual inspection may not provide information underneath the surface, sample drilling is time consuming and data is collected at discrete locations.
Ground penetrating radar (GPR) can be used to assess railroad ballast fouling conditions. GPR can collect data along the railroad track non-destructively, continuously and rapidly. However, the GPR data collected from ballast are complex and difficult to interpret. The interaction of electromagnetic (EM) wave with ballast, which is an inhomogeneous medium, is much more complex than that with cement concrete or asphalt pavement, which are usually considered in GPR data interpretation as homogeneous media. Currently there are several approaches to interpret GPR ballast data, including time domain approach, time-frequency approach and wavelet approach. Wavelet approach is the most advanced approach since it can interpret GPR data continuously, automatically and without interpreters' subjectivity. This paper proposes a further development of current wavelet approach. The proposed new method considers the interpretation of GPR data as a texture analysis and texture retrieval problem. A database of GPR images with known fouling levels (0% fouling or clean ballast, 10%, 20%, 30% and 40% fouling level) will be established. Wavelet transforms and feature extraction will be performed on each image. Each image can then be represented by its feature vector. The GPR images collected on ballast with unknown fouling levels will be used as query images. The same feature extraction method will be performed to extract feature vectors from the query images. By comparing the feature vector from each query image with the ones in the database, the most similar image in the database can be identified. The query GPR image is assigned with the fouling level of the matched GPR image in the database. During the process, different feature extraction methods will be tried, including L1-norms, L2-norms and parameters from generalized Gaussian density (GGD) model. Different similarity measurements will also be tested including using Kullback–Leibler distance (KLD). The best feature extraction and similarity measurement method is identified based on the highest retrieval rate.