Image Analysis as an Alternative to Ballast Grain Size Investigation

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One of the main criteria for determining the quality of track ballast is grain size distribution. It is expected that the ballast size falls within a defined range, with larger rocks in the 25–63 mm range making up the bulk of the ballast according to the standard. In Norway, Bane NOR (Norwegian Railway Administration) specifies that the maximum ballast size should be 73 mm, with no more than 10% of the content above 63 mm, no more than 10% below 25 mm, and a maximum of 0.5% below 1.6 mm [1].

This means that, at certain defined periods or under specific circumstances—such as when a ballasted track does not perform as expected—an investigation is required. When inspecting ballast, various tools can be used, but the most common method involves digging up a ballast sample, sending it to a lab for assessment, and ensuring it meets the required standards. This assessment method is long and tedious because train traffic must be stopped to allow for ballast excavation, transportation of often heavy samples to the lab for analysis, and then waiting for the conclusion on whether the ballast meets the required standards.

Camera technology is becoming increasingly affordable, and advanced image recognition algorithms are more readily available. Several successful applications of image analysis have also been demonstrated, such as in coal quality analysis [2], particle size distribution of landslide debris [3], and gravel analysis [4], to mention a few. This opens the possibility of using image analysis tools and image recognition software to investigate ballast grain size distribution. This method allows ballast to be assessed on-site at the start of maintenance activities and replaced immediately if necessary, improving both time efficiency and cost-effectiveness.

This study offers a preliminary exploration of using image analysis tools as an alternative to traditional ballast assessment methods. Using ImageJ, an open-source image processing software, two distinct algorithms were applied: edge detection thresholding and adjustable watershed segmentation. These algorithms were used to analyze ballast sample images under varying conditions. The research examined the effects of three key variables on image analysis accuracy: rock size, arrangement, and lighting. Experiments were conducted on ballast rocks of different sizes, arranged in ordered, scattered, and piled configurations, with and without additional lighting. A total of sixty analyses were performed to evaluate the effectiveness of the method.

The results indicate that image analysis has the potential to serve as a viable alternative to traditional ballast assessment methods, with watershed segmentation demonstrating higher accuracy in identifying individual ballast particles. However, challenges remain, particularly with complex arrangements and low-contrast conditions.

References:

[1] NS-EN 13450:2013 – '*Aggregates for Railway Ballast'*, Norwegian Standard.

[2] R. Gao, J. Yin, R. Liu, Y. Liu, J. Li, L. Dong, W. Ma, L. Zhang, P. Zhang, Z. Tian, Y. Zhao, W. Yin and S. Jia, *'A novel particle size distribution correction method based on image processing and deep learning for coal quality analysis using nirs-xrf* ,' Talanta, vol. 285, p. 127-427, 2025.

[3] S. Karunarathna, S. Goto, S. Bandaranayake and P. Bandara, *'Identification of the complete particle size distribution of landslide debris by the combined method of scaled image analysis, line-grid analysis and laboratory sieve analysis,'* Geoenvironmental Disasters, vol. 11, no. 1, 2024.

[4] J. Wu, L. Wang, Y. Hou, H. Xiong, Y. Lu and L. Zhang, *'A digital image analysis of gravel aggregate using ct scanning technique,'* International Journal of Pavement Research and Technology, vol. 11, no. 2, p. 160–167, 2018.