Title:
Planimetric Rail Positioning Using UAV Photogrammetry: Towards Automated and Safe Railway Infrastructure Monitoring

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Level of study or work: PhD

Information about you (and your team): The Geomatics Group of the Department of Civil Engineering focusses on developing new methods to survey infrastructure. Our group of researchers with various specialties tackles interdisciplinary challenges. Suzanna Cuypers has a background in geography & geomatics, having studied at various universities across the world including UCSD (USA), Ghent University (Belgium), KUAS (Taiwan), and KU Leuven (Belgium).

Area of interest

The use of Unmanned Aerial Vehicles (UAVs) for railway monitoring has emerged as a significant research topic because of its potential to replace traditional manual inspection methods, which are time-consuming, subjective, and pose safety risks. Additionally, inspections are often postponed when tracks cannot be taken out of service, compromising effective monitoring. Therefore, the exploration of UAVs for rail monitoring is of utmost importance to ensure safe railway operations.

UAVs equipped with Lidar or optical cameras offer promising capabilities for aerial surveys. While Lidar provides accurate depth information, optical imagery is more suitable for precise edge localization. This study focuses on utilizing UAVs to accurately position tracks and measure gauge, which refers to the distance between the inner rails — a crucial factor for ensuring safety in railway operations.

To detect and localize tracks in imagery, various edge detection and line extraction algorithms can be employed. Previous research by (Karakose et al., 2018) employs traditional techniques such as Canny edge detection and Hough transformation. However, advancements in deep learning models provide new approaches for edge detection and line extraction. Their performance on rails has not yet been explored.
It is worth noting that the detection of linear elements is not limited to railway monitoring. Similar techniques have been successfully applied to other domains such as crane tracks in container terminals (Costantino et al., 2019; Ghassoun et al., 2021) and power lines (Zhao et al., 2022). This highlights the broader applicability and significance of this research beyond the railway industry.

Approach to the problem

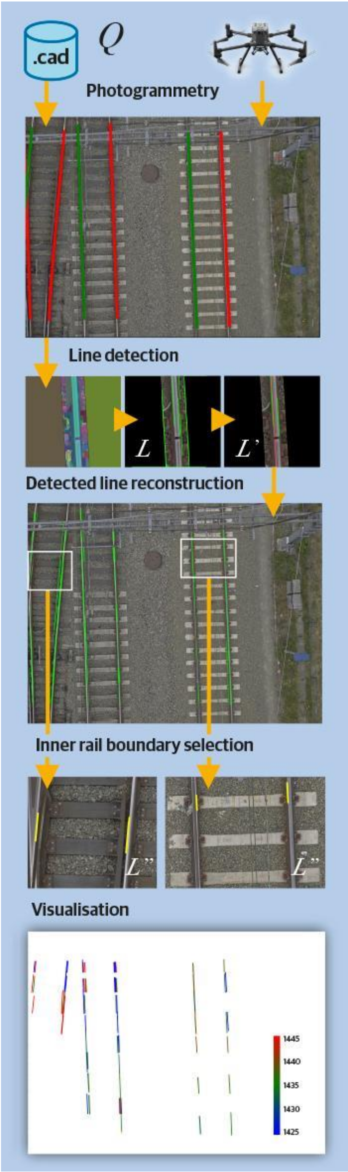

Figure 1 Workflow for planimetric rail survey

Photogrammetry

In order to obtain Cartesian transformation matrices, all images are photogrammetrically aligned in Agisoft Metashape, so that as-designed rails can be reprojected on the images. The georeferencing is achieved using Ground Control Points (GCPs) and the RTK GNSS information. Using the projected as-designed rail lines, the irrelevant areas can be masked. The large images are tiled before the next step.

Line Detection

Lines are detected in the tiles to obtain set L. False positives are filtered out using the location and orientation of the as-designed lines to obtain subset L'.

We experiment with different line detection methods. One of these is a segmentation method. Segmentation, as done by (Guo et al., 2021) to detect railroad components in imagery, can indeed be useful to localize the edges of rails in a more robust way. Therefore, we apply the Segment Anything Model (SAM), released in May 2023 by Meta (Kirillov et al., 2023), to rail imagery in order to test its performance on rails.

Inner Rail Boundary Selection

Since only the inner rail boundaries are relevant to determine gauge and planimetric deviation from the as-designed rails, we conditionally select line pairs from set L' and evaluate the detected lines in all images. The line pairs are saved in set L''.

Gauge and Deviation Maps

Using each line pair, the gauge can be determined using pixel distance and GSD. The gauge offset and planimetric offset from the as-designed rails are represented using a visual color map.

Results, conclusions and next steps

Results

We have tested five different methods to detect rail edges in UAV imagery: Canny, HED, DexiNed, SAM, and M-LSD. Figure 2 shows the required different processing steps.

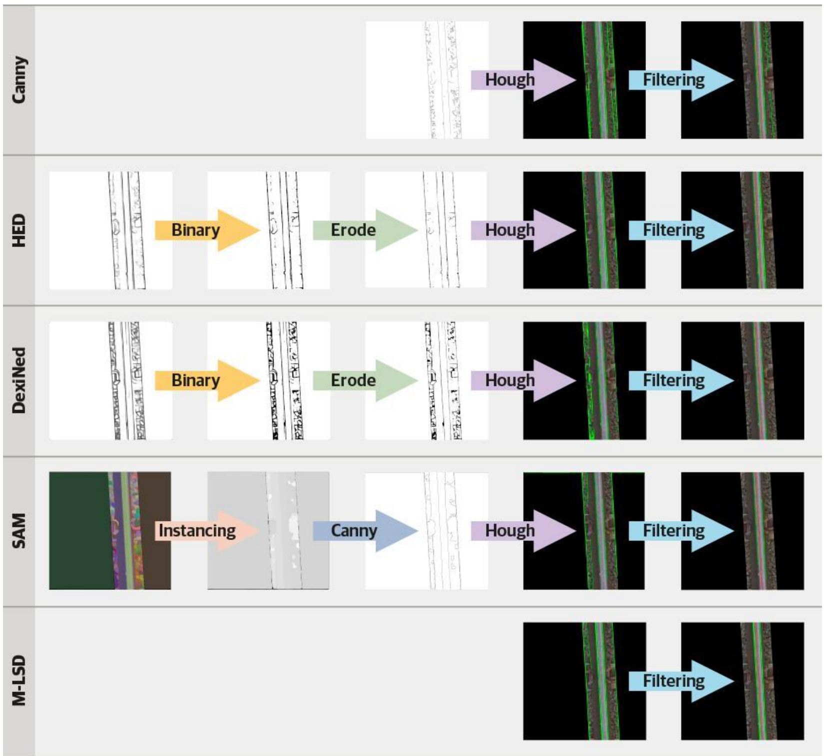

Figure 2 The required processing steps to extract lines using five different methods.

We find that SAM produces very little false positives, but requires intensive processing. M-LSD and HED, on the other hand, generate overlapping lines, but yield quick results. A fair balance can be found with DexiNed, many short lines are detected without overlap and processing speeds are significantly faster than with SAM.

The obtained output consists of gauge and absolute deviation maps (Figure 3). The planimetric deviation from the as-designed rail lines ranges from 0 to 30 mm. Even though the rails of the middle track do not lie in the intended location, their gauge, as shown in the left map, is still within the tolerance.

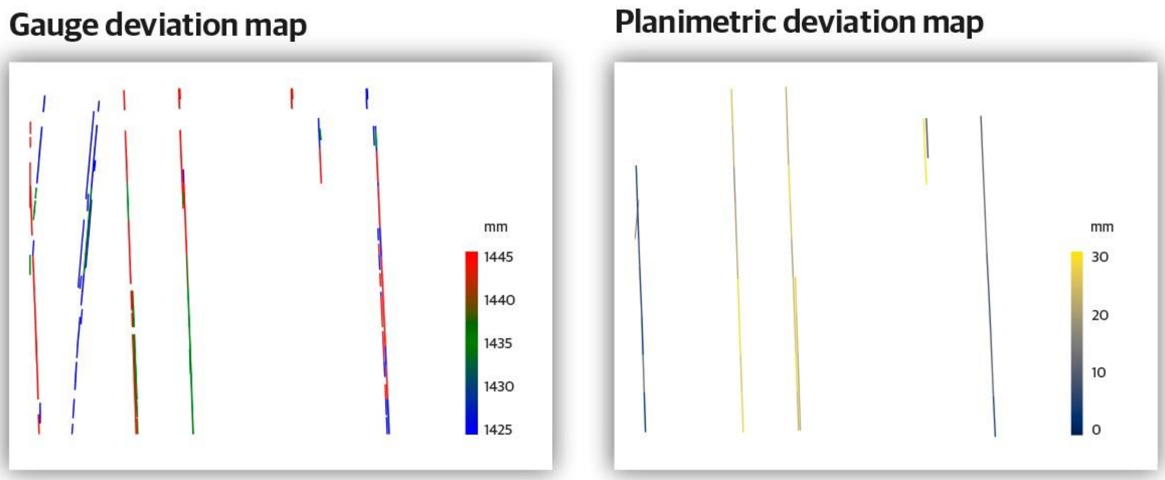

Figure 3 Visualization of track gauge and deviation of inner track edges from the as-designed rails in mm.

Contributions

The novelty of this work lies in the UAV photogrammetric workflow, its application of novel edge-detection techniques, and the visualisation of planimetric deviations.
This work will be presented at the ISPRS 2023 Geospatial Week, Egypt.

Next Steps

This framework will be expanded to 3D by including either Lidar or oblique imagery, so that a photogrammetric point cloud or depth information can be extracted.

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