8TH INTERNATIONAL ISPRS WORKSHOP

LOW-COST 3D - SENSORS, ALGORITHMS, APPLICATIONS

Railway reconstruction from 3D point cloud using Deep Learning and Parametric Modeling

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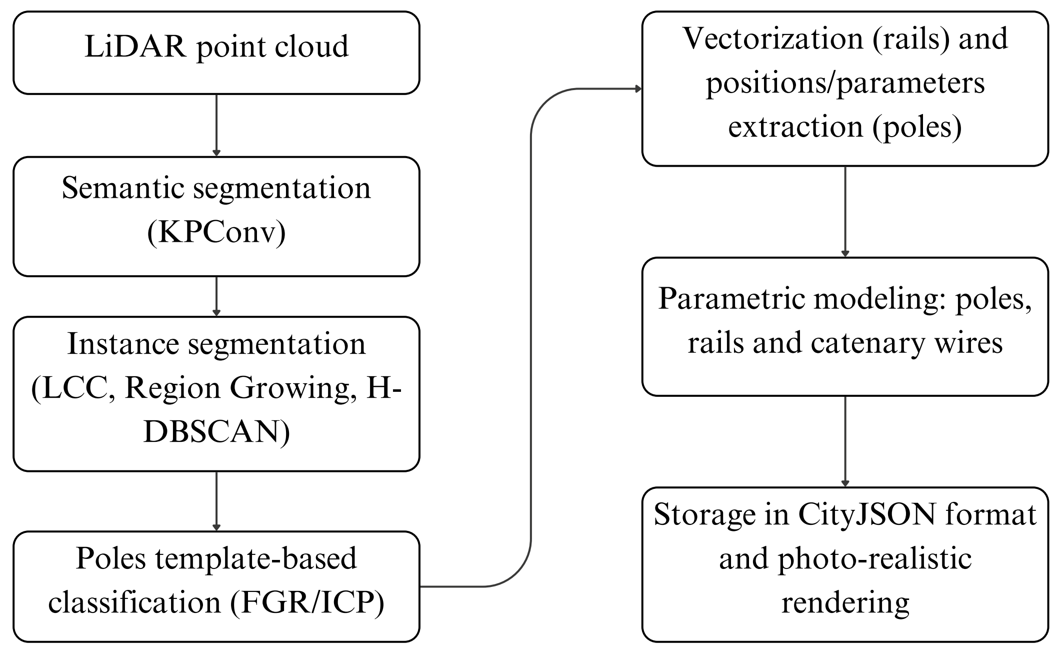
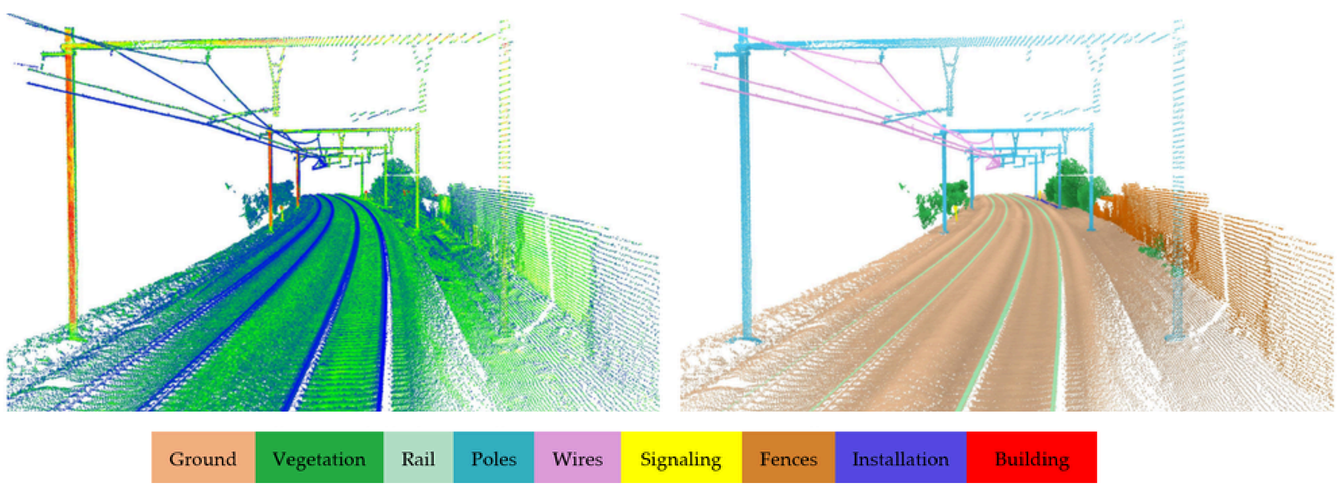
Railway infrastructure is crucial for transporting goods and passengers, making its maintenance and reconstruction vital for safety and reliability. Traditional methods reliant on manual surveys are time-consuming and prone to inaccuracies. Although 3D point cloud data provides detailed representations of railway environments, its unstructured nature complicates processing and modeling. This paper presents a methodology that combines deep learning with parametric modeling to reconstruct railway environments from 3D point cloud data, focusing on key components such as rails, catenary wires and poles. This study presents a methodology that combines deep learning with parametric modeling to reconstruct railway environments from 3D point cloud data, focusing on key components such as rails, catenary wires and poles. The results are represented in a standardized CityJSON format, in compliance with the Transportation module of CityGML 3.0, and textured to create photo-realistic 3D railway models.

Methodology

Our approach combines deep learning and parametric modeling to reconstruct railway environments from 3D point cloud data, focusing on rails, catenary wires, and poles, and exporting the results in CityJSON format. The process begins with semantic segmentation using a KPConv model trained on the Rail3D dataset to classify points into categories like ground, rails, poles, and wires. Instance segmentation of catenary poles is performed using the Label Connected Components (LCC) algorithm in CloudCompare, followed by classification through template matching and global registration with Fast Global Registration (FGR) and Iterative Closest Point (ICP) algorithms. Rails are segmented using Region Growing and H-DBSCAN clustering, then vectorized, connected, and refined with buffering and centerline extraction, with missing sections reconstructed as needed. Finally, parametric modeling is applied to the extracted components, which are exported in standardized CityJSON format for integration into digital models. Textures are also added for photo-realistic rendering.

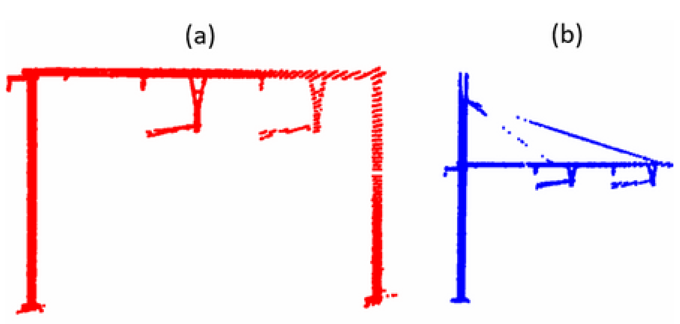




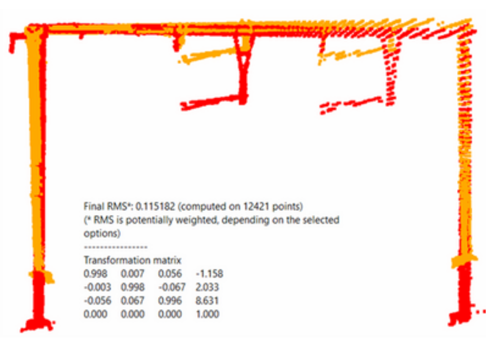
Approach	OA	mIoU	Ground	Vegetation	Rail	Poles	Wires	Signaling	Fences	Installation
KPConv	0.99	0.84	0.99	0.84	0.95	0.97	0.99	0.40	0.69	0.89

Catenary pole template database

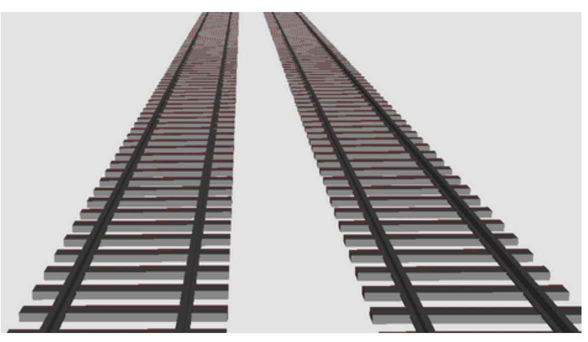
Key railway environment components were reconstructed in 3D, guided by semantic and instance segmentation. Catenary poles were modeled using extracted height and orientation parameters, ensuring alignment with track geometry, while cantilever structures supported the catenary system. Wires were reconstructed to reflect their natural sag and connectivity, forming a comprehensive 3D representation of the railway infrastructure. The models adhered to the "Transportation" module of CityGML3.0 and its CityJSON encodings, ensuring compatibility with urban modeling frameworks and facilitating integration into digital twins. Textures were applied to enhance realism, creating a photorealistic visualization of the railway environment.



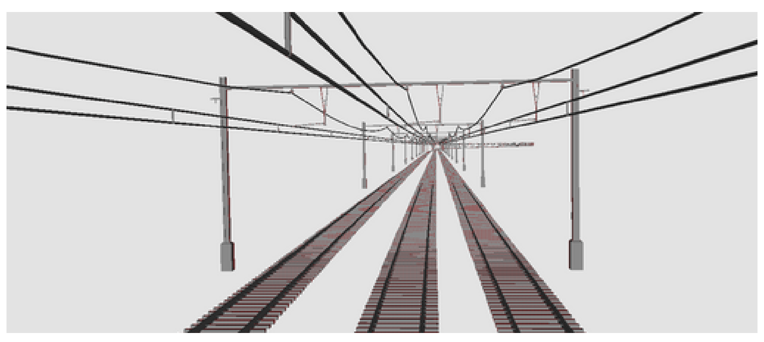
Catenary pole template database



FGR/ICP registration results



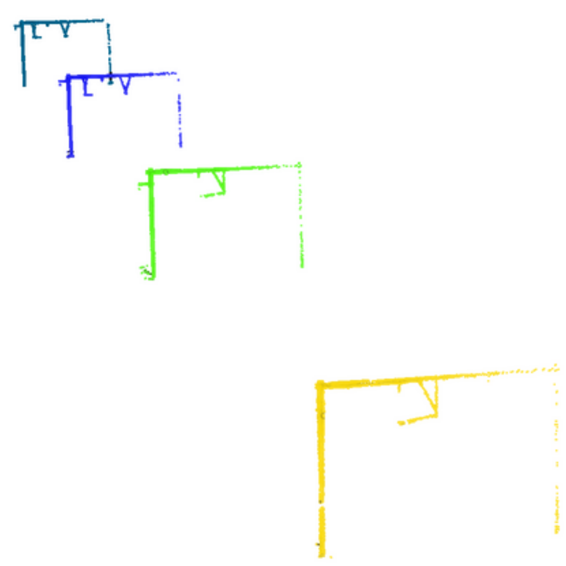
Tracks (rails ans sleepers)



Catenary poles and wires

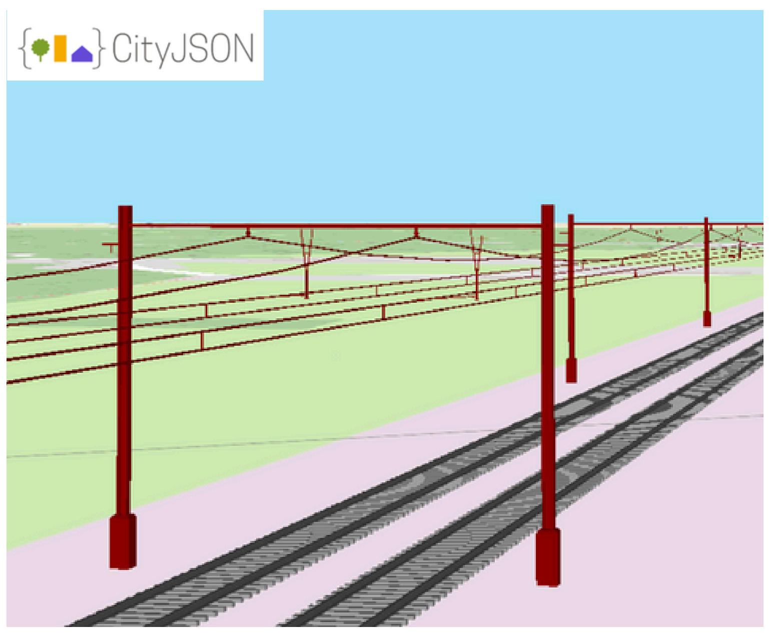
Results and discussion

Our methodology was tested on railway point cloud data between Andenne and Huy, Belgium, yielding promising results. The fine-tuned KPConv model achieved a mean Intersection-over-Union (mIoU) of 84% in semantic segmentation, effectively classifying railway LiDAR data even without RGB values. Quantitative results, including overall accuracy (OA), mIoU, and IoU for relevant classes, confirmed the model's high performance. Instance segmentation of catenary poles using LCC was successful, with minimal matching errors in classification via pre-defined templates and FGR/ICP registration. Registration RMSE ranged from 10 to 30 cm, influenced by data completeness and occlusions. Rail vectorization resulted in a continuous, accurate rail model, effectively connecting line segments even with noise or gaps.



LCC segmentation results

Rails before and after linearization



CityJSON model

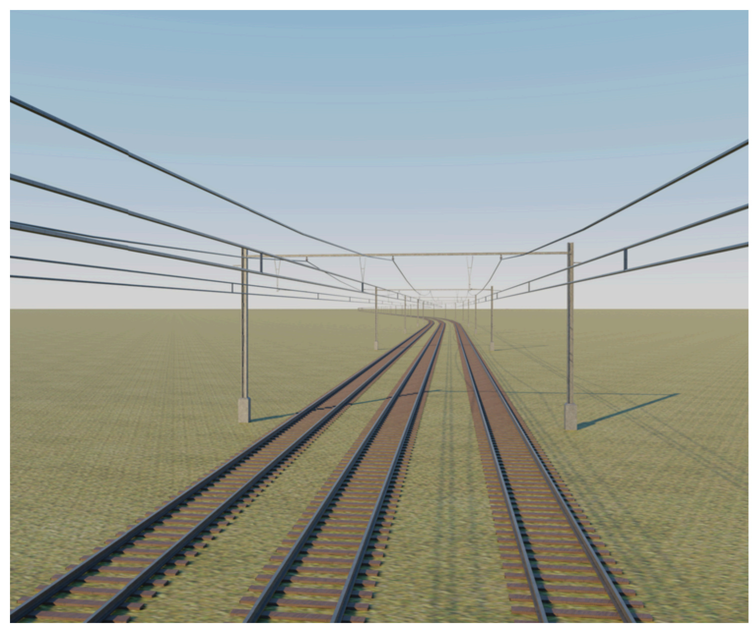


Photo-realistic 3D railway model