**Title**

3D Road Boundary Mapping of MLS Point Clouds

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**Abstract**

Roads in modern cities facilitate different types of users, including car drivers, cyclists, and pedestrians. These different users often have a designated section of the road to operate on. Road management, e.g., by municipalities, needs to take this sectioning into account, preferably in an efficient way. Mobile laser scanning (MLS) point clouds provide accurate and dense three-dimensional (3D) measurements of road scenes, showing strong mapping capabilities, although their massive data volume and lack of structure still bring difficulties in automatic processing. Methods for the automatic classification of road surface types are still largely lacking, and the existing methodology did not consider the potential of MLS point clouds yet. In recent years, point cloud understanding through deep neural networks has achieved breakthroughs. However, perceiving large-scale point clouds by deep learning depends on aggregating local features and progressive downsampling, to extract rich contextual information. As a consequence, low-level features that reveal details in point clouds may not be well preserved, possibly resulting in ambiguous delineation in point cloud classification. For road mapping, inaccurate classification of points on road boundaries hinders the generation of high-quality map products. Some existing deep learning methods propose to mitigate the fuzzy classification near boundaries, either by utilizing refinement for network predictions, or by indirectly modifying neighboring weights when summarizing local information. Approaches to achieving a satisfying overall performance, while maintaining accurate delineation, still need investigation. In this study, we propose a novel approach for road type classification of MLS point clouds in dense urban areas based on a deep neural network. We follow the main architecture of RandLA-Net, a point-wise neural network designed for large-scale point cloud processing. To alleviate the ambiguous delineation of point cloud classification, we propose two strategies. The first is to refine predictions of RandLA-Net by conditional random field. In the second strategy, we incorporate boundary constraints in the network by introducing a novel distance label for each road surface point to represent the distance to its closest boundary. The distance prediction task is combined with road type classification by adding another branch in RandLA-Net to formulate multi-task learning. Through experiments, we show that 3D point cloud semantic segmentation by deep learning is applicable for road type classification. Also, the multi-task learning strategy is verified to be more effective in improving the delineation performance. Using MLS point clouds acquired from 5 German cities (Hamburg, Delmenhorst, Bremerhaven, Hannover, and Oldenburg), we classify road points separately into different usages (sidewalk, cycling path, rail track, parking area, motorway, green area, and island without traffic) and materials (cobblestone, asphalt, plates, unpaved, and railway). When adopting Hannover and Oldenburg for testing, and the other three cities for training, we obtain a mean intersection over union of 46.1% for usage type and 52.0% for material type with the multi-task learning strategy and input features (x, y, z, R, G, B, intensity), outperforming the original RandLA-Net by approximately 4%. Moreover, from the point cloud classification results, we achieve lightweight polygon representations of road objects in different types through post-processing, which is demonstrated to perform better than an image semantic segmentation-based solution quantitatively and qualitatively.