Digital Twins of Building Extraction from Dual-Channel Airborne LiDAR Point Clouds

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Abstract:

The new dual-channel airborne LiDAR system can acquire dense point clouds of roofs and facades at the same time, RIEGL VQ-1560i has the most advanced dual-channel LiDAR system with unique and innovative bi-directional scanning angles, which provides better building instance extraction than traditional Scanner for more complete and precise data. This abstract presents the first point cloud building extraction for urban digital twins using dual-channel airborne LiDAR data. The main challenges of this lidar data are the large number of points, complex data structure, and multiple classes of objects. We propose a preprocessing-free architectural extraction method. It consists of three steps, namely point cloud slicing, projection, and constraint-based extraction of labels. Point cloud slices consist of top-down merging of elevation and 3D semantic segmentation to reorganize point cloud scenes into interrelated point groups. This greatly reduces the processing difficulty and computational burden of complex structures while removing multiple classes of non-building points. Second, we project the point group into an image to further reduce computational complexity while improving processing efficiency. Finally, we label the building with its up-down relationship and remap it as a 3D building. Experimental results show that the proposed method achieves an average recall rate of 95.36% and an average F1 score of 93.59%. For digital twin instance segmentation, the quality of the two public test scenarios reaches 92.86% and 98.31%, respectively.

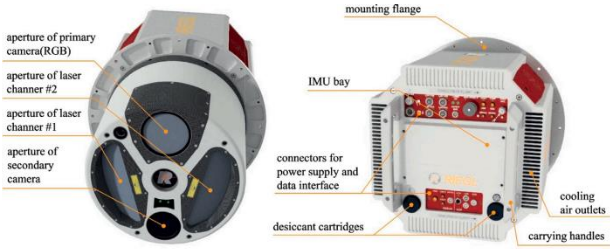

Figure 1. Example figure, placement, caption and numbering: the famous ICA logo.

For point cloud data, non-terrestrial objects have vertical geometry, but the point distribution is disorderly and uneven due to different shapes, reflectivities, and scan angles. Complex and incomplete structures of real-world buildings with occlusions and local similarities are between different buildings. In addition, due to measurement errors, the laser scanning process produces sparse outliers, which complicate the local features of the point cloud and lead to processing errors. Compared with other lidar data, dual-channel lidar data provides denser and more detailed point cloud scenes, which pose more stringent requirements and challenges for 3D building extraction. RIEGL VQ-1560i is a state-of-the-art lidar system (RIEGL, 2019). As shown in Figure 1, the dual-channel system is capable to operate at an altitude of up to 5600 meters, and the maximum measurement speed reach 1.33 million times per second (meas./s). Dual-channel design provides a unique revolutionary front-to-back two-way simultaneous scanning function, enabling to more effectively and accurately collect high-point-density data from multiple angles within 60 degrees of the field of view (FoV). The multi-pass (MTA) processing of up to 20 pulses simultaneously in the air, point clouds of facades between buildings with an angle of less than 16 degrees.

This paper presents a novel instance-level building extraction method for point cloud scenes collected by a dual-channel airborne LiDAR system., The proposed method consists of three modules: (1) point cloud reorganization module (green dashed area), (2) projection and detection module (blue dashed area), and (3) labeling and extraction module (purple dashed area). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

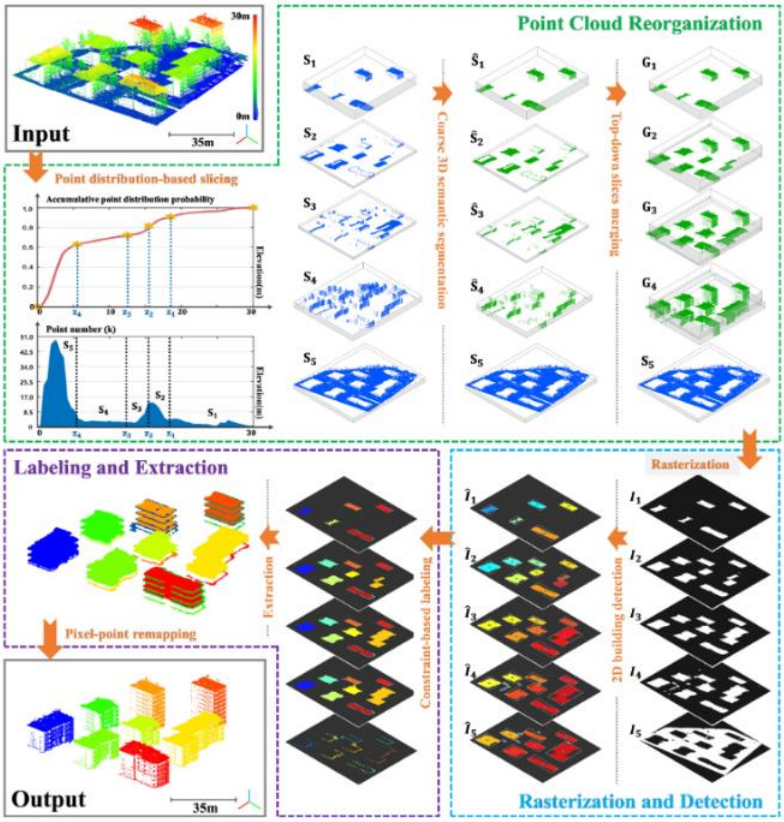

Fig. 3. Workflow of the proposed preprocessing-free building extraction method.

In this paper, six ALS point cloud scenes are used for testing, including four scenes from our own dataset and two from public datasets. We evaluate the semantic-level building extraction performance utilizing recall, precision and F1-scor.Furthermore, we follow the instance-level evaluation of Wu et al. (2020) and Zhang et al. (2021) and same definitions of IoU (intersection over union). The experimental results were evaluated with instance-based evaluation. The quantified results that presented in Table 5 show that our approach outperforms the benchmark methods on VAIHI-1 and DALES-1. More specifically, for VAIHI-1, the completeness, correctness and quality of our method is better than all the others. For DALES-1, the completeness and quality of our method is higher than all the others, and the correctness higher than that of the MV, ES2D,ES3D and LCCP.

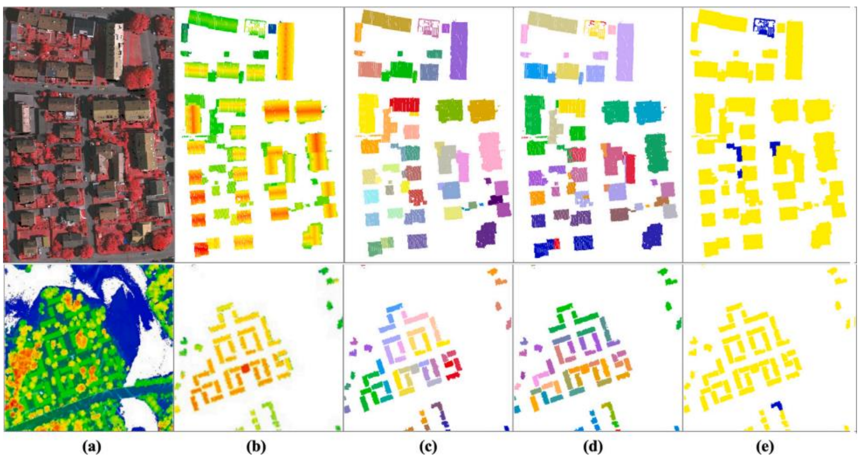

Fig. 7. Instance-level building extraction results on VAIHI-1 (first row) and DALES-1 (second row).

Fig 7(a) is original aerial image corresponding to VAIHI-1in the upper line. The lower line shows the point clouds of the entire scene corresponding to DALES-1. Fig 7(b) Point clouds of VAIHI-1 (upper) and DALES-1 (lower). Points in Fig 7(a) and (b) are colored by heights. Fig 7(c) is the instance-level ground truth. (d) shows the extraction results of our method. In Fig 7 (c) and (d), different building instances are displayed with different colors. Fig 7(e) Main differences between the extraction results of our method and the ground truth (yellow: correctly extracted; blue: over-extracted). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Experimental results on six test point cloud scenes demonstrate the outstanding performance of the proposed preprocessing-free method. For semantic-level performance, our method achieved 95.36% in average recall and 93.59% in average F1-score on four test scenes from our own dataset in the semantic-level performance. As for the instance-level performance, our approach reached 92.86% and 98.31% in quality on two test scenes from public datasets, respectively. Since the proposed method can hardly extract all buildings from point cloud scenes with large slopes, our future work will utilize the normal-based plane and slope transformation to increase the building extraction quality from such scenes.

Acknowledgements

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