Integration of Digital Photogrammetry and Laser Scanning Technique for Generating High-Quality 3D Point Clouds

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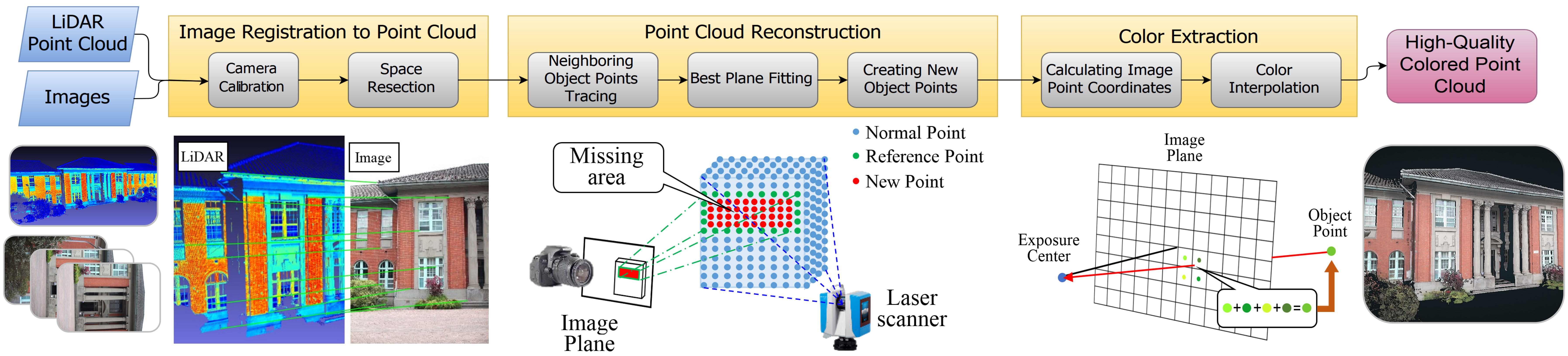
ABSTRACT

Light Detection and Ranging (LiDAR) technology is capable of acquiring point cloud data quickly with great accuracy and high density. However, for a complex scene, missing areas frequently occur as a result of occlusion, reflection, and other optical factors. In this study, an image-based approach for point cloud reconstruction and densification is presented. In the case where the missing areas can be identified from image data, the proposed method requires only one single image to reconstruct the point cloud of missing areas. In addition to filling the missing area, the abundant spatial and spectral information from an image can be used to densify the raw LiDAR data, providing more details on texture information. An outdoor experiment on building facade has been conducted in this investigation. By applying the proposed, missing areas like window glasses or occluded walls have been successfully reconstructed. Moreover, this approach has improved the visual quality of LiDAR point cloud, achieving more realistic data for subsequent applications such as 3D modelling.

METHODOLOGY



RESULTS AND ANALYSIS

● Single image-based point cloud reconstruction

Neighboring object points of missing area will serve as reference points for obtaining the plane equation of the missing area. Once the plane equation of the missing area is known, new object points can be created by marking pixels within the missing area and intersecting their image-object vectors with the known plane. Consequently, point cloud reconstruction with image-based resolution and centimeter-level accuracy can be achieved.

Image patches on different planar structures were first manually specified with different colors as the Figure 4a depicts below. All the object points colored with the RGB values from the mentioned two images, as shown in Figure 4b.

(a) (b)

Figure 4. (a) Areas to be reconstructed and densified (b) A result of point cloud reconstruction

● Numerical Validations

In order to provide a quality evaluation, one image was used as ground truth, which contained the detailed information about the densified areas. By resampling color values from these image points with the same resolution as the image, two interpolated images can be obtained (Figure 5).

To evaluate the quality of the images as mentioned above, three common objective image quality metrics were used in this study, the Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM). These objective image assessment measures were introduced to measuring the difference between the resulting images and the ground truth. The resulting values are listed in Table 1.

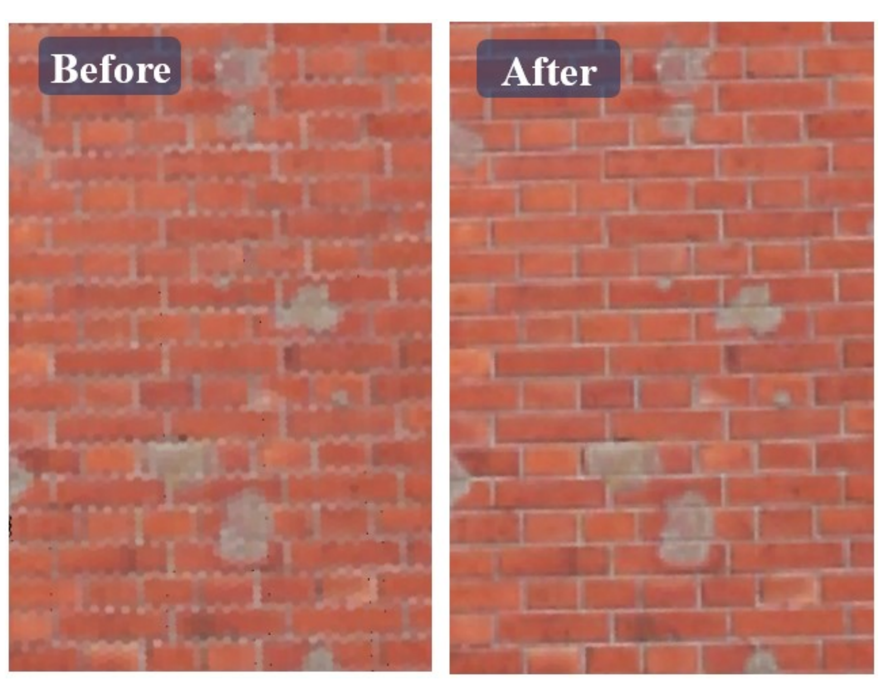


Table 1. Image quality metrics before and after applying the proposed approach

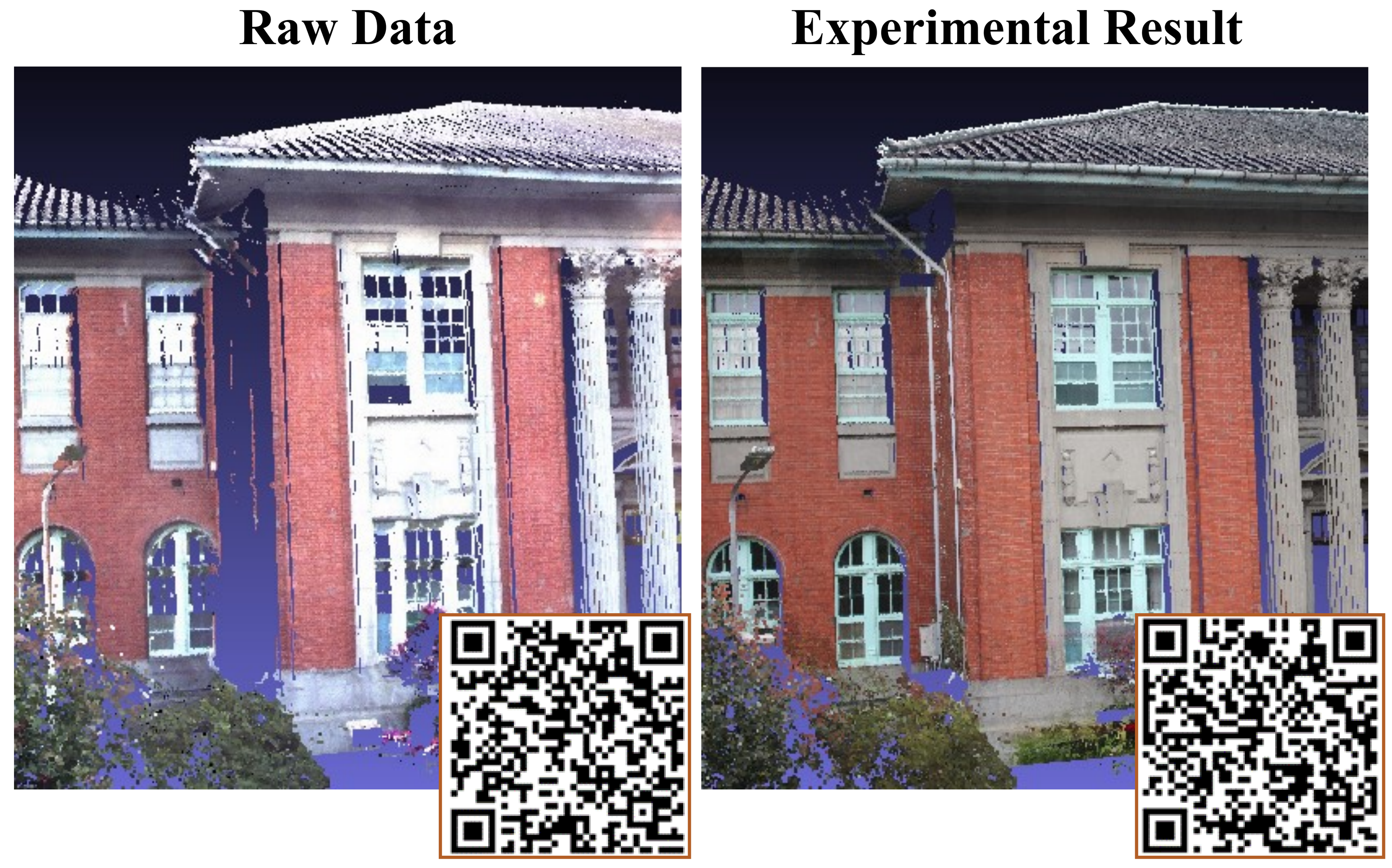
	Image quality metrics		
	MSE	PSNR	SSIM
Before	82.62	9.79	0.77
After	55.48	13.25	0.84
Improvement	32.84%	35.34%	8.41%

Figure 5. Images resampled from the point cloud projected onto the image plane of "IM03N"

● Visual Demonstration

The point cloud data before and after applying the proposed approach are shown in the following figure. A web-based interface is used for demonstrating of the point cloud data. One can get a more comprehensive understanding of the improvement achieved in this study by accessing the QR Codes below.

Raw Data **Experimental Result**



CONCLUSIONS

In this study, an image-based approach for point cloud reconstruction was presented. First, the camera exterior orientation parameters were determined by manually selecting correspondences between LiDAR point cloud and an image and a single-image resection algorithm was applied. By assuming the planar geometry whose normal vector can be estimated using the neighboring points of missing area, high-quality object points were then created, filling up the missing area in the point cloud. **The result indicates that the proposed approach is capable of providing a more complete and realistic result. It has been demonstrated that the improvement from 8.41% to 35.34% in the adopted image quality metrics can be achieved after applying this approach.** This means that an integrated approach can lead to a more desirable outcome rather than using only a single technique. The resulted photorealistic point cloud has also shown the efficiency and the reliability of the developed approach in this study.

ACKNOWLEDGEMENT

This research is supported by Ministry of Science and Technology in Taiwan (under contracts No. 105-2119-M-002-050).