Segmentation and Classification of Lidar data

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Abstract: Laser scanning has become a viable technique for the collection of a large amount of accurate 3D point data densely distributed on the scanned object surface. The inherent 3D nature of the sub-randomly distributed point cloud provides abundant spatial information. To explore valuable spatial information from laser scanned data becomes an active research topic, for instance extracting digital elevation model, building models, and vegetation volumes. The sub-randomly distributed point cloud should be segmented and classified before the extraction of spatial information. This paper investigates some exist segmentation methods, and then proposes an octree-based split-and-merge segmentation method to divide lidar data into clusters belonging to 3D planes. Therefore, the classification of lidar data can be performed based on the derived attributes of extracted 3D planes. The test results of both ground and airborne lidar data show the potential of applying this method to extract spatial features from lidar data.

Keywords: Lidar, Laser Scanning, Segmentation, Classification, Octree

1. Introduction

Laser scanning, commonly called lidar, is a novel technique for the collection of a large amount of accurate 3D point data densely distributed on the scanned object surface [1]. The inherent 3D nature of the sub-randomly distributed point cloud provides abundant spatial information. To explore valuable spatial information from lidar data becomes an active research topic, for example extracting digital elevation model, buildings, and trees from lidar data [2, 3].

Segmentation is generally prerequisite for extraction of spatial information from lidar data. Most segmentation techniques were developed for 2.5D grid data or image data. An interpolation procedure is needed to apply an image-based segmentation technique to lidar data. Although several successful cases of applying image-based segmentation and classification (S/C) to airborne lidar data have been reported, the problems of interpolation and the loss of data information have also been frequently addressed [4-7]. Eventually, new S/C methods suitable for lidar data are needed. This paper proposes a split-and-merge method based on octree structure to divide lidar data into clusters belonging to 3D planes. The segmented planes then can be classified according to the attributes derived from each 3D plane. The proposed method would suitably work for airborne lidar data as well as ground-based lidar data. Some tests on both kind of lidar are demonstrated to show the application potential of the proposed method.

2. Related Segmentation Work

Due to the lack of ad hoc segmentation methods for lidar data, the use of well developed image-based segmentation methods has been the rule of thumb choice in the past few years, especially the applications of airborne lidar. Scanning from the air, airborne lidar offers point cloud near homogenously distributed on the scanned ground surface, which can be treated as 2.5D surface models except the areas with multiple echoes or scanned vertical walls. In this case, a height image can be obtained by interpolating lidar data to regular grid. Therefore, image-based segmentation methods, such as edge detection, and region growing, filtering etc., can be employed to handle airborne lidar data, for example extracting urban features or buildings from lidar data [8] [9, 10]. However, the interpolation based on 2.5D space frequently causes the information loss or distortion in the vertical dimension, especially the parts of multiple echoes and vertical walls. It is also quite obvious that these techniques are no longer feasible to apply to ground lidar data.

Although exploring the 3D nature of lidar data is preferable, a commonly accepted 3D segmentation method is still not available. Mass and Vosselman [5] suggest the use of original 3D data to derive building models, but their approaches are limited to work on a segmented point cloud of a building, which is obtained by using height data filtering or available 2D GIS data. A generally accepted 3D segmentation principle is extract geometric information by fitting surface patches. This idea was originally proposed by Hoffman and Jian [11], but the implementation was still based on a 2D region-growing method. Woo et al. [12] proposed a new segmentation method for point cloud data generated with industrial short-range laser scanners. The merit of the proposed algorithm is to use the octree-based 3D-grid method to handle a large amount of unordered sets of point data. In general, this 3D segmentation method is also suitable for airborne and ground lidar data. However, this method requires well-ordered scan lines to form triangulated grid. Airborne lidar data does not fulfill this requirement due to multiple echoes and aircraft motion. It does not satisfy the requirement either, when a point cloud data set composed of several scans.

3. Test Data

The test data applied in this paper include an airborne lidar data set collected in Hsinchu, Taiwan with Leica ALS40 (Fig. 1) and a ground lidar data set obtained in Tainan Confucian temple with Optech ILRIS-3D laser scanner (Fig. 2). Table 1 lists the basic data attributes. The airborne lidar data set contains some multiple echoes.

Table 1 Information of examples.

	ALS40	ILRIS-3D
Scan Date	April 14 ,2002	January 24, 2003
Scan Area	Hsinchu	Tainan Confucian temple
Point density	About 1.7pt/m²	About 1136pt/m²
Point cloud size	4700	247427

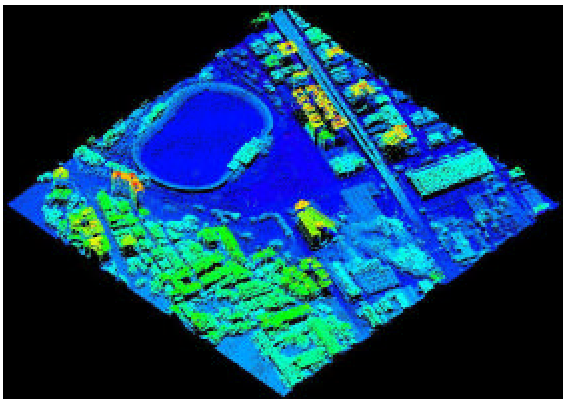

Fig. 1 ALS40 test airborne lidar data.

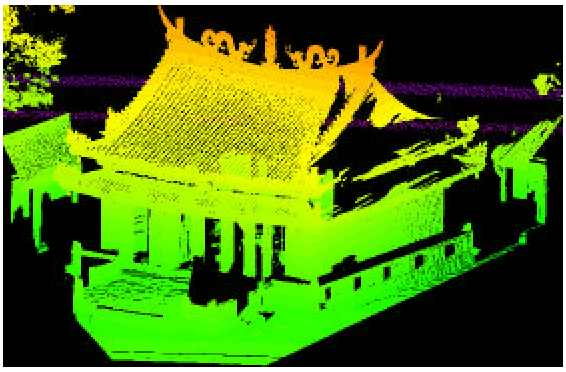

Fig. 2 Optech ILRIS-3D test data.

4. Split and Merge Segmentation Based on Octree Structure

In accordance with the 3D segmentation principle, the proposed method is to segment point cloud into clusters each of that fits a 3D plane. A split and merge algorithm based on the octree structure is developed. The split process starts from the whole data set as a root node. The data set space will be divided into 8 sub-spaces, represented by 8 sub-nodes, if the point cloud inside does not fit a plane. In the fitting test, the best-fit plane in each sub-space is determined using least-squares estimation, then the distance from each point to the best-fit plane is calculate for test. If there is a distance larger than the preset distance threshold, then a split process is needed. In order to ensure the segmented fitting planes corresponds to scanned surfaces, the distribution density of the point cloud on the best-fit plane is also tested by a density threshold for split. Each sub-node will be split continuously until the point cloud contained in the split space of the sub-node fits a 3D plane or is less than 3 points. After splitting, the merge process searches for neighboring planes in the octree structure, then merges the neighboring planes if they are similar.

The segmentation method extracts 3D geometric features from a lidar data set. It dose not require well-ordered scan lines. It can handle any kind of point cloud data set, including airborne, ground, and industrial lidar data. Lidar data with multiple echoes or merged from multiple scans can be handled as well.

This 3D segmentation procedure results in segmented 3D planes organized in the octree structure. Each plane contains densely distributed point cloud. Treating the planes as extracted features, feature attributes, such as gradient, area size, point density, roughness, and average intensity etc., can be calculated for further analysis or classification. Based on the segmentation results, the potential of plane-based classification is investigated in the next section.

5. 3D Plane-Based Classification

A classification can be performed based on the attributes of the extracted 3D planes. In this preliminary study, we have not developed a well classification method. However, simple classification results based on single attribute shows the potential of the feature-based classification. Fig. 3, 4, and 5 show the simple classification results of the airborne lidar data based on average intensity, average height, and plane gradient respectively. We can see that the ground planes and some of the roof planes were extracted quite well. The classification based and average height shows a good separation of ground planes and roof planes. Through the analysis of the plane shape, area, orientation, and symmetry, well classification of the extracted planes can be expected. Fig.6 shows the classification result of the ground lidar data based on the plane gradient. The planes of the roof, ground floor, and vertical walls are classified quite well in this example. Building modeling would become possible by analyzing the intersection of the extracted planes [3, 5]. The classification can be further elaborated to extract various meaningful features or to filter unwanted data out.

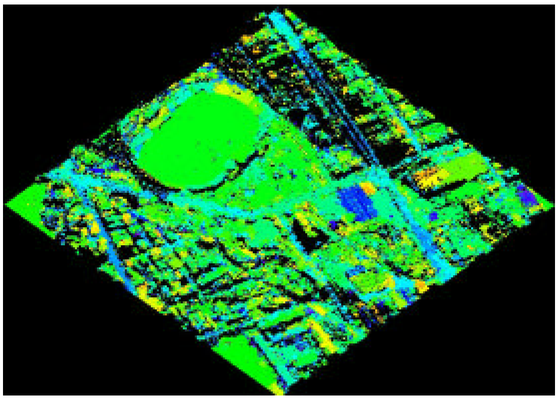

Fig. 3 Classification of the airborne lidar data based on average intensity.

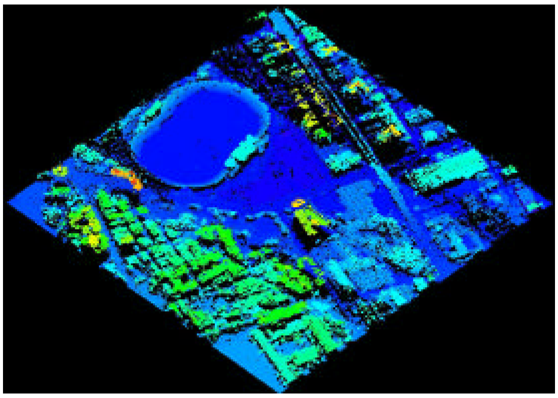

Fig. 4 Classification of the airborne lidar data based on average height.

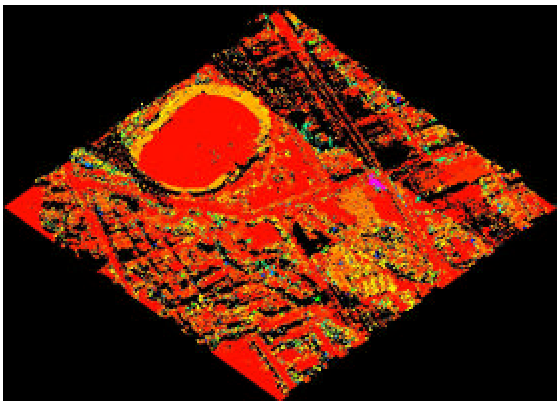

Fig. 5 Classification of the airborne lidar data based on plane gradient.

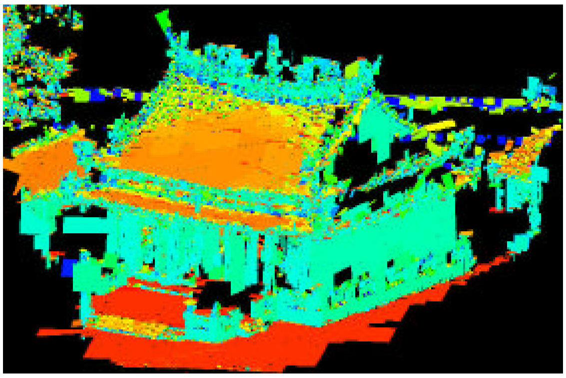

Fig. 6 Classification of the ground lidar data based on plane gradient.

6. Concluding Remarks

Sub-randomly distributed point cloud of lidar data needs an ad hoc segmentation method for the extraction of spatial information from lidar data. This paper proposes an octree-based split-and-merge segmentation method to divide lidar data into clusters belonging to 3D planes. The preliminary classification results of airborne and ground lidar data based on the derived attributes of extracted 3D planes show the potential of applying this method to extract spatial features from lidar data. The classification can be elaborated to extract buildings or specific urban features as well as to filter unwanted data out. Building modeling will also be possible by analyzing the intersection of the extracted planes.

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