

DATA FILTERING AND FEATURE EXTRACTION OF URBAN TYPICAL OBJECTS FROM AIRBORNE LIDAR POINT CLOUD

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ABSTRACT:

The research in the detection and feature extraction of typical objects in urban areas has intensified. In existing detection technologies, it has been shown that the LIDAR technique is very promising and suitable for 3D object detection mainly because 3D sub-randomly spatial distributed point cloud represented the object's geometrical structure can be obtained easily and instantly. In this paper, the points' spatial distribution characteristics of LIDAR data are analyzed firstly. Then, a slope-based planar-fitting filtering algorithm of LIDAR data is presented based on the analysis of the spatial distribution feature of LIDAR point cloud. This algorithm is used for the experimental research of data filtering and feature extraction of LIDAR data in urban area. The experimental result shows that this algorithm is able to extract more effectively objects feature.

1. INTRODUCTION

With the availability of many techniques such as photogrammetric, SAR, IFSAR, and LIDAR (Light Detection and Ranging), there are many methods to object detection and feature extraction in urban areas [1]. Through much research, it has been considered that the LIDAR has more potential to support 3D object detection and feature extraction than others [2]. It can survey topographic information more detailed and accurately. However, the data set obtained by LIDAR system is sub-randomly spatial distributed 3D point cloud that represents points from both the ground surface and objects found on the ground surface. Hence, the ground points and points representing such objects have to be filtered and extracted from LIDAR point cloud for further applications. Therefore, developing efficient filtering methods is currently an active topic of research.

In the past, several methods have been developed for data filtering and feature extraction of the LIDAR data [3,4,5,6,7]. The ISPRS Commission III/WG3 has tested a number of filtering algorithms [8]. The results of the test have been compared through the society's web site (www.commission3.isprs.org/wg3/). In many algorithms, the region growing [9] and the least square interpolation method [10] are two commonly used methods, and the mathematical morphology method [11] also shows some advantages in some feature extraction process. However, the interpretability of LIDAR point cloud is often limited due to the fact that no object information is provided, and the complex earth topography and object morphology make it impossible for a single operator to classify all the point cloud precisely 100%.

This paper presents a new planar-fitting filtering algorithm of data filtering and feature extraction for LIDAR data. The ground and building are the most typical objects in urban area, so in this paper the filtering algorithm mainly is used to filter and extract the ground and building information. The content of

this paper is organized in four sections. In Section 2, the points' spatial distribution characteristics of LIDAR data are analyzed. After that, a new planar-fitting filtering algorithm is presented. Then, the method of building top extraction from the filtered point cloud based on the planar-fitting filtering algorithm is discussed further. In Section 3, a filtering and feature extraction experiment to LIDAR data with this algorithm is performed and the result is described and discussed. The conclusions are drawn with respect to the objectives set out in Section 4.

2. METHODOLOGY

2.1 The spatial distribution of LIDAR point cloud

Commonly, an airborne LIDAR system is mainly comprised of a laser scanner, a GPS receiver, and an Inertial Navigation System (INS) [12]. It transmits very short pulses or a modulated signal in the visible or near infrared part of the electromagnetic spectrum by the laser scanner, and records the position and orientation of the aircraft at each transmission of pulse through the GPS and INS [13,14]. Through the record of the round-trip travel time, the system can obtain 3D coordinates and intensity value of each ground reflection point.

LIDAR data can be characterized as 3D discrete sub-randomly spatial distributed point cloud as Figure1 shows. Different typical object has different spatial distribution characteristics. Generally, in building top or ground, there is only one echo and spatial distribution of point clouds that is regular in range. However, laser pulse can penetrate vegetation to return multiple echoes. Every echo has different height value, so the vegetation point clouds are irregular distribution. And to vertical object like building wall, it usually can be generated sparse irregular LIDAR point cloud because of the less laser point hitting or reflected and refractive effects by glass or others.

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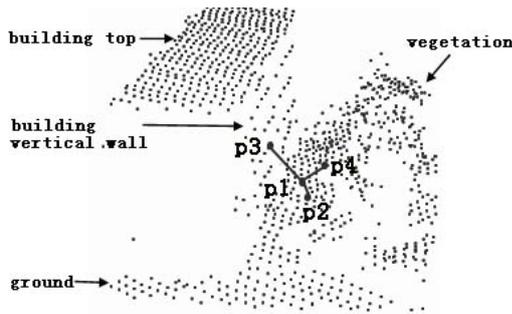


Figure 1. The spatial distributed illustration of LIDAR point cloud

According to the spatial distribution characteristics of LIDAR point cloud, the building top and ground usually have no distinct topographical changes and height-jump features. So, the building top or ground can be treated as smooth horizontal plane in some sense. The building vertical wall can be treated as smooth vertical plane too if there are enough laser points. As Figure 1, the slope between the ground point P_1 and the ground point P_2 is small, so point P_1 and P_2 can be regarded belonging to the same plane. But the slope between the ground point P_1 and the building vertical wall point P_3 or the vegetation point P_4 is large, so P_1 and P_3 or P_4 are not regarded belonging to the same plane.

Based on the above analysis of the spatial distribution characteristics of LIDAR point cloud, a slope-based planar-fitting filtering algorithm of LIDAR point cloud can be presented.

2.2 Planar-fitting filtering algorithm

The Planar-fitting filtering algorithm will congregate some LIDAR points that have enough small slope changes into the same plane point set. This plane in the algorithm is not the plane as $Ax+By+Cz+D=0$, but the continuous smooth surface. In order to regard this surface as approximate plane, some parameters must be set in this Planar-fitting filtering algorithm. The parameters illustration in Planar-fitting filtering algorithm is as Figure 2 (for example horizontal plane).

Point P_1 belongs to the plane I. The point P_2' is the projected point of P_2 in plane I, r is the distance between P_2' and P_1 , h is the height difference between P_2 and P_1 , and α is the inclination of point P_2 to plane I. If point P_2 can approximately belong to the same plane I with P_1 , then the following terms must be satisfied:

- (a) r is less than the distance threshold Threshold_r ;
- (b) $|h|$ is less than the height difference threshold Threshold_h ;
- (c) $|\alpha|$ is less than the inclination threshold Threshold_α .

The Threshold_r , Threshold_h and Threshold_α are predefined threshold parameters based on different topography and density of point cloud.

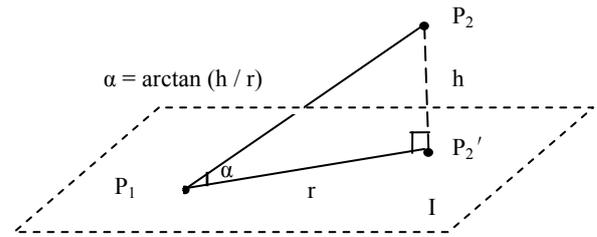


Figure 2. The parameters illustration in Planar-fitting filtering algorithm

The Planar-fitting filtering algorithm can be described as following:

Planar-fitting filtering (Threshold_r , Threshold_h , Threshold_α , Filtered, UnFiltered)

Initialize the value of parameters: the array of Vicinity as neighboring points set, r as the distance, h as height difference, α as the inclination;

Take out the first point from set UnFiltered into set Filtered as central point ctl_pt ;

Repeat

Search all neighboring points of ctl_pt in Delaunay Triangle Network and add these points into the array of Vicinity;

Take out one point from array Vicinity as object point obj_pt ;

Calculate the distance between ctl_pt and obj_pt into r , the height difference into h , the inclination into α ;

If $r \leq \text{Threshold}_r$ and $h \leq \text{Threshold}_h$ and $\alpha \leq \text{Threshold}_\alpha$, then add obj_pt into set Filtered;

Until Vicinity is empty;

UnFiltered = UnFiltered - Filtered;

The description of the Iterations filtering algorithm based on Planar-fitting is as following:

Planar-fitting_Iterations_filtering (Pt_Cloud , Threshold_Pnum , Filtered, UnFiltered)

If Pt_Cloud is empty, then exit;

Set UnFiltered = Pt_Cloud ;

Construct Delaunay Triangle Network of Pt_Cloud ;

$i=1$;

Repeat

Planar-fitting filtering (Threshold , Threshold_h , Threshold_α , Filtered, Unfiltered);

Calculate the number of points in set Filtered into Pnum ;

If $\text{Pnum} > \text{Threshold_Pnum}$, then move points from set Filtered into array $\text{planeclass}[i]$, $i=i+1$;

Else move points from set Filtered into array $\text{planeclass}[0]$; ($\text{planeclass}[0]$ is the non-plane set)

Until UnFiltered is empty;

In this algorithm, the parameters settings have strong impact on the filtering results, so the strategy of parameters setting is important. We will consider roughly the actual topography information and LIDAR point density information so as to set sound parameters values in the algorithm process. Generally, Threshold_r and Threshold_h are set as one to two times of average distance and average height difference respectively, and Threshold_α is 10° to 20° . Large threshold value may magnify the erosion effect.

2.3 Building top extraction

We can filter the horizontal continuous ground points and planar building top points using the above Planar-fitting filtering algorithm successfully. Between the filtered ground points set and the filtered building top point sets have obvious height difference as the 3D figure of some filtered points showing in figure 3. The figure 4 is the histogram of Z value about filtered ground and building top points. From figure 4, the ground points are continuous distribution and height differences between points are smaller. Usually the area of ground is larger than the total area of building tops, so the number of points in ground point set is larger than one in all filtered plane point set. To building top, different building has the different height value of building top, so the building top points are continuous distribution in different subsection and the number of building top points is smaller than ground points. Based on the above analysis, the point set which average height is smallest and number of points is largest will be considered the ground point set in all filtered plane point sets. So, the building top points can be extracted by subtracting the ground points from all filtered points.

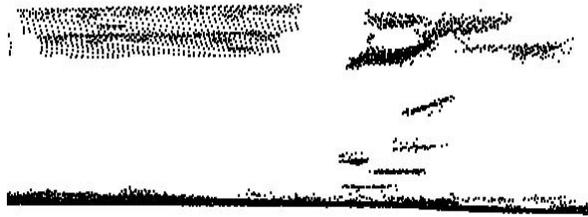


Figure 3. 3D figure of filtered ground and building top points using Planar-fitting filtering algorithm

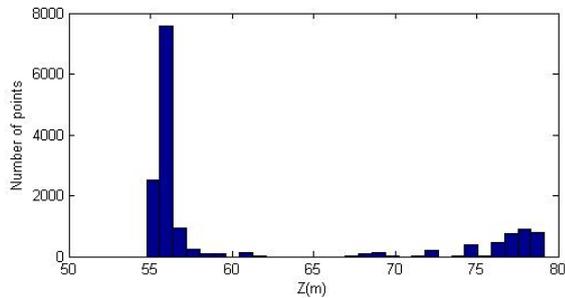
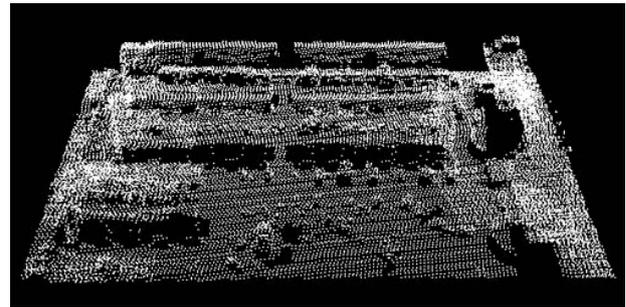


Figure 4. Histogram of Z value about filtered ground and building top points using Planar-fitting filtering algorithm

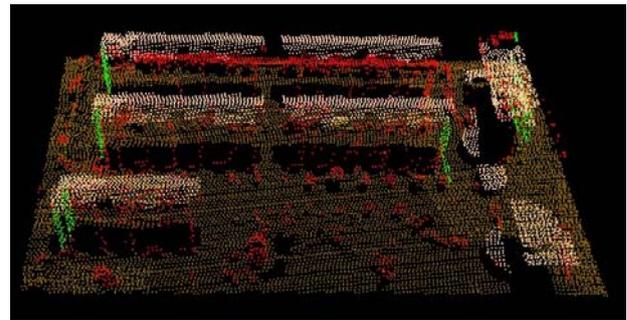
3. TESTS AND RESULTS ANALYSIS

In this study of experiment, the ground, building top and building wall points in city area will be extracted using the Planar-fitting filtering algorithm. The LIDAR data in this test is obtained with LiteMapper-5600 LIDAR system. It can retrieve up to 5 returns from a given pulse. The average point spacing is about 1.77m. The data filtering and feature extracting results are as Figure 5. The Fig.5.a shows the original LIDAR point cloud and the Fig.5.b shows the data filtering results of different planes. In the data filtering process, the parameters settings of horizontal plane filtering are Threshold_r=2.0, Threshold_h=1.0, Threshold_α=15, and that of vertical plane filtering are Threshold_r=5.0, Threshold_h=0.5, Threshold_α=15. The feature details of building top and building wall are described in

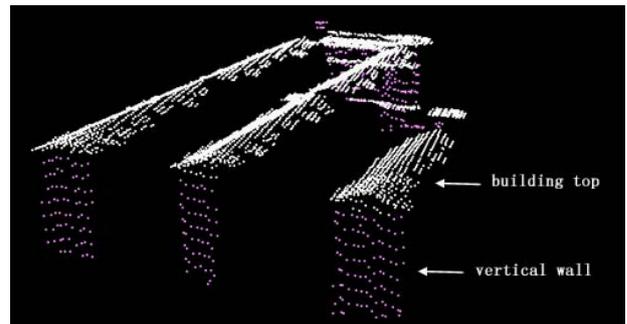
Fig.5.c. But only one side of building wall can be filtered in this test because of generating sparse point in other sides restricted by direction of laser scanning.



(a) Original LIDAR point cloud



(b) Data filtering results



(c) The feature details of building top, building wall

Figure 5. The data filtering and feature extracting results in city area

4. CONCLUSIONS

The LIDAR is very promising technique for 3D topography detection and object extraction, so developing effective data processing methods is important. In this paper, a slope-based planar-fitting filtering algorithm of LIDAR data is presented based on the analysis of the spatial distribution feature of LIDAR point cloud. In this study of experiment, the LIDAR points in the horizontal planes such as ground and building top and in the vertical planes such as building wall in urban area will be filtered using the above Planar-fitting filtering algorithm. And the building top points can be extracted from the filtered plane point sets. The test results show that, using the algorithm, it is possible to get a better filtering and feature extracting result.

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