

STUDY ON THE TARGET FEATURE EXTRACTION FROM LIDAR POINT CLOUDS

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ABSTRACT:

With the rapid development of remote sensing technology, three dimensional coordinates and intensity information of observation target can be obtained directly from LIDAR system. It is one of the important issues in the study on LIDAR data processing that how to extract the object from the point cloud data captured by laser scanning effectively without the help of spectral information as well as other auxiliary data. In this paper, a method for the target extraction from the point cloud data in the absence of other auxiliary data is proposed. Experiment results indicate that the mentioned method can extract interesting object points from LIDAR point cloud data powerfully.

1. INTRODUCTION

Light Detection and Ranging (LIDAR) merges Global Positioning System, Inertial Navigation System and Laser Scanning System to acquire the 3D coordinates of the object points directly, which can complete the extraction of earth surface information and reconstruction of 3D objects (Liang Xin-lian, 2005). It can capture the 3D geometry information and laser impulse reflection intensity of a certain object. Simultaneously, it has many advantages such as high spatial resolution and high spatial positioning accuracy. The most of key issues in the terms of hardware and system integration of LIDAR have been resolved, while LIDAR data processing algorithm is still under study.

LIDAR data processing includes post-extraction and filtering of the point cloud by distinguishing that of planimetric point and topographical point (Deng Fei, 2006). In this paper, the ground objects extraction from the LIDAR is discussed in detail. Firstly, the range image will be presented based on the laser point cloud data. Secondly, the extraction method of lines, rectangles, circles as well as irregular shapes is proposed based on the Canny operator and Hough transform so that the object of interest can be found automatically.

2. BASIC THEORY

In this paper, the first step of target extraction view of the shape features of object area is based on the Canny operator and Hough transform. The Canny operator is now widely used in edge detection (Sui Li-chun, 2002). The advantages of the operator are high accuracy in edge positioning and distinction of weak edges and fake edges. However, edge features cannot be captured with the only use of Canny operator.

The extracted edge pixels can be assembled by Hough

transform to become the meaningful outline, so that the polygons as well as irregular targets can be extracted (Zhang Xiao-hong, 2002). The advantage of the Hough transform lies in the fact that it is still effective when the image contains incomplete information of the object or additional structure, such as other straight lines, curves or objects.

The key of Hough transform is the calculation of Hough matrix. Given an analytical formula $f(\mathbf{x}, \mathbf{a})=0$ defined by the contour curve of the target, where \mathbf{a} is the parametric vector. The accumulator of each parameter is generated according to their expectant range and a certain step size. Hough matrix represents the parameter space quantified by the accumulator and the index of each dimension exactly matches with an accumulator. The initial value of Hough matrix is zero. For every coordinate vector \mathbf{x} which matches a edge pixel, the elements in the matrix could add 1 if these elements make the value of the $f(\mathbf{x}, \mathbf{a})=0$ close enough to zero. When this calculation completes, local maximum in Hough matrix is considered to be a curve appeared in original image which fits $f(\mathbf{x}, \mathbf{a})=0$. During the search of local maximum, the maximum number of curves and the lower limit of maximum are set to ensure that the curves could be found to fit the analytical formula enough (Rafael C. Gonzales, 2003).

3. TARGET EXTRACTION METHOD

3.1 Data Pre-processing

The X and Y coordinates can be sampled renewedly to create gray image. The grey value of each pixel is corresponding to the height of each LIDAR point cloud data. The size of image is determined by point density. In this paper, there are 2 to 4 points in the area where a pixel covers averagely. Then a binary image can be obtained using the Canny operator.

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3.2 Straight Line Extraction Using Hough Transform

The analytic equation of straight line is defined as below

$$x \cos \theta + y \sin \theta = \rho \tag{1}$$

so Hough matrix with two dimensions (ρ, θ) is generated. Given a edge pixel, every value of the θ accumulator determines a certain ρ according to the equation (1), rounding this ρ to match a value of the ρ accumulator, the corresponding element in Hough matrix is added by 1. The complete Hough matrix can be achieved after this operation is done for every edge pixel.

Every local maximum in the Hough matrix corresponds to a straight line, so we can get the parameters of this straight line directly, the pixels which belong to this line can also be found. Then other processes such as filling small gaps, exclusion of isolated pixels is carried out to get line segment.

Further process is able to be performed to extract polygons such as rectangles.

3.3 Circle Extraction Using Hough Transform

The analytic equation of circle is defined as below:

$$(x - a)^2 + (y - b)^2 = r^2 \tag{2}$$

so Hough matrix with three dimensions (a, b, r) is generated. Given a edge pixel (x, y) , every value of (a, b) in a and b accumulator determines a certain r according to equation (2). Rounding this r to match a value in r accumulator, the corresponding element in Hough matrix is added by 1. After this operation is done for every edge pixel, the complete Hough matrix is acquired. Similar as straight line, the position and corresponding pixels of the circles or arcs in image can be obtained by finding local maximum in the Hough matrix.

3.4 Irregular Shape Extraction Using Generalized Hough Transform (GHT)

A huge difference between generalized Hough transform and the above-mentioned Hough transform is the way of description of the target boundary. Hough transform describes the target boundary using analytical equations, due to no corresponding analytical equation for irregular shape, generalized Hough transform uses a table containing a group of discrete parameter (Li Ziqiang, 2006).

Relative coordinates	Right pixel	Below pixel
$(x_1, y_1), (x_2, y_2) \dots$	0	0
...	0	1
...	1	0
...	1	1

Table 1. Example of reference table

According to different formats of the parameter table, there are

various ways to perform generalized Hough transform (Liu De-gang, 2005). In this paper, a reference table shown in the table 1 is used for the transform.

Given a binary template of the irregular shape, the values of the right pixel and the below pixel for every edge point are checked. So we can classify them into four classes as shown in the table 1. Each class contains several points and their relative coordinates to the designated reference point (commonly inside the shape) are recorded in the first column of the table.

According to this reference table, targets with a shape similar as the template can be positioned by searching the reference point in the image. Firstly, Hough matrix with two dimensions for the coordinates of the reference point is generated. Then every edge pixel point in the image is classified by checking its right pixel and below pixel. According to the classes, several possible reference points can be calculated using the relative coordinates searched in the table 1. Those elements of the Hough matrix is mapping to the coordinates of possible reference points and is added by 1. At last, the maximum in the Hough matrix is consider to be the reference point so that the irregular shape is extracted.

4. EXPERIMENT RESULTS

Three kinds of targets are extracted from LIDAR point cloud data using the above mentioned method. The original point data is a las type file containing a high density point cloud, which is about 3 to 4 points per m^2 .

4.1 Extraction of Line Segment

The range image of the region with many rectangle targets is shown in the Figure 1(a). Canny operator was carried out and the result was given as the figure 1(b). Then line segments were detected using Hough transform and painted red in the figure 1(c). It can be seen that the line segments were extracted well and truly. On the basis of the results, the rectangle outline can be obtained shown in figure 1(d).

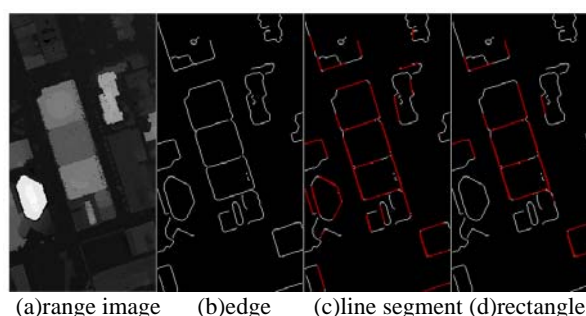


Fig 1. The Experiment results of Line Segment Extraction

4.2 Extraction of Circle

The figure 2(a) shows range image of a region with obvious circle targets. Canny operator was carried out and the result is shown in the figure 2(b). Using Hough transform, we can extract one circle and several arcs shown in the figure 2(c).

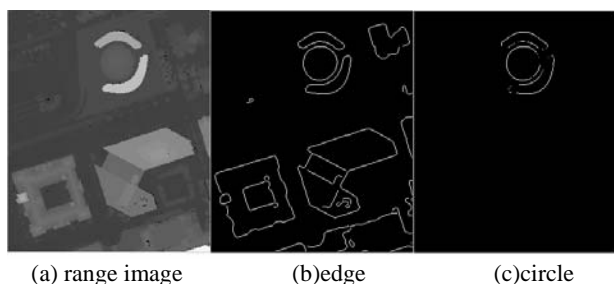


Fig 2. The Experiment results of Circle Extraction

4.3 Extraction of Irregular Shapes

As we can see, the range image of the figure 3(a) is same as the region in the figure 1(a). The difference between the two experiments is that the target of interest has been changed to the high building on the left of bottom. A template of this building is shown in figure 3(b). The red plus indicates the reference point. In the figure 3(c), the reference point was found exactly the same position relative to the building after generalized Hough transform performed.

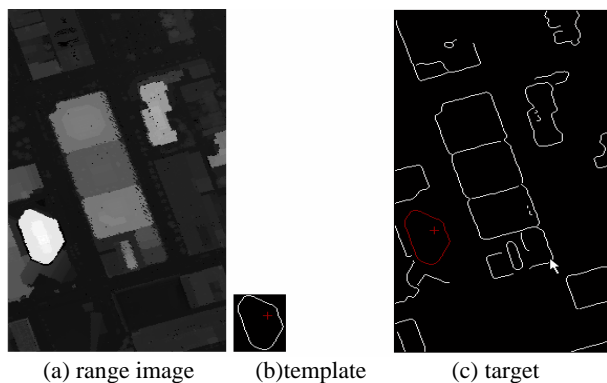


Fig 3. The Experiment results of irregular shapes Extraction

5. CONCLUSION

In this paper, the characteristics of LiDAR point cloud data and the analysis of Hough Transform is discussed in depth. A method for target feature extraction from point cloud is proposed in the absence of auxiliary data. Three groups of experimental results in the fourth part of the paper demonstrate that the effectiveness of the proposed algorithm for extracting interesting objects.

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