LINEAR FEATURE EXTRACTION OF BUILDINGS FROM TERRESTRIAL LIDAR DATA WITH MORPHOLOGICAL TECHNIQUES

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Abstract:
LiDAR has been a major interest of photogrammetry to acquire three dimensional objects. It has shown its promising capabilities in building virtual reality applications, such as virtual campus and virtual historic sites. However, point clouds of LiDAR data always occupy a large sum of storage capacity. This blocks further fast processing of LiDAR data to combine with GIS to build virtual reality. The research focused on linear feature extraction of buildings from terrestrial LiDAR data. To obtain linear features of buildings is one of the critical steps to realize minimization of redundant data and high efficiency of data processing. The paper discussed the procedure of linear features extracting of buildings and mainly put forward edge detection algorithms based on fractal dimension theory. Triangular method was chosen to obtain fractal dimension values of grids. The algorithm was not only effective and efficient to detect building edges, but also helpful for segmenting the building and nature objects. Future work was also discussed in the end.

1. INTRODUCTION AND BACKGROUND

Since LiDAR is typically not weather dependent and can be carried out over areas where a conventional survey would be extremely difficult or damaging, it has increasing applications in various fields. Up to the end of 2006, there are approximately 150 LiDAR systems provided by commercial manufacturers worldwide active today (BC-CARMS, 2006). Some of them are TopScan, Optech, TopSys and Leica. China also has its own LiDAR systems. ShuKai Li led a group and developed an airborne LiDAR system in 1996. Qingquan Li developed a terrestrial LiDAR system in his lab (Lai Xudong, 2005).

At present, most software packages of LiDAR data processing have inability to efficiently handle the immense volumes of data captured by LiDAR sensors and don’t provide modules to realize the function linear feature extraction. Many researchers pay a lot of interests on this topic to improve the situation. Most of them tried to realize the function with airborne LiDAR data processing. Digital Surface Models (DSM) was put forward to push the function realization (Paolo G., Bijan H. 2000). Texture-based segmentation was used to tell different regions of landform (Arko L. and Alfred S. 2004). Fuzzy reasoning and information fusion techniques were also put forward for demonstration (F. Samadzadegan. 2004). And some researchers tried to use multi-resolution wavelet filters to get better result of linear feature detection from LiDAR data (Samuel P. K. and R. H. Cofer. 2005). To improve the character of real-time processing, parallel algorithm for linear feature detection was demonstrated to be useful (Manohar M. and Paul C. 2006). Some researches just face the challenges of automatic image segmenting. Automatic construction of building footprints from airborne LIDAR Data has been testified (Zhang K. Q., Yan J. H. and Chen S. C., 2006). Recently, expectation-maximization method was used to classify aerial LiDAR data (Suresh K. L., Darren M. F. and David P. H, 2007). Some researchers combined several methods to improve effect of the segmenting and classifying, such as region growing, size filter and k-means classification methods were used to extract building class from LiDAR DEMs (George M. and Nikolaos K. 2007). Most of these researches were focused on airborne LiDAR data processing. Terrestrial LiDAR system is relative simple. However, its data has different characters from that of airborne LiDAR system. The raw airborne LiDAR data are recorded alone the flight line when the data were collected. However terrestrial LiDAR data are collected from different static spots. And it has relatively small detecting radius. Usually, it can obtain more abundant and precise information of objects. These make some difference in data processing of raw terrestrial LiDAR.

This research focused on linear feature extraction of buildings from terrestrial LiDAR data. Point clouds of LiDAR data always occupy a large sum of storage capacity. It is common that data volume of one building may take more than 200MB and there are some files in the CLICK (the Center for Lidar Information, Coordination and Knowledge) website that are about 2 GB large (Qi Chen, 2007). To obtain linear features of buildings is one of the critical steps to realize minimization of redundant data and high efficiency of data processing. This research is initial work carried out at the National Centre for Geocomputation Ireland for virtual campus building in 2007.
The paper discussed the procedure of linear features extracting of buildings and mainly put forward edge detection algorithms based on fractal dimension theory. Triangular method was chosen to obtain fractal dimension values of grids. The algorithm was not only effective and efficient to detect building edges, but also helpful for segmenting the building and nature objects. Future work was also discussed in the end.

2. DATA COLLECTION, DATA CHARACTERS AND BASIC SOFTWARE

The experiment data were collected with Leica HDS3000 on the campus of NUIM (National University of Ireland, Maynooth). The target is John Hume Building. The equipments are shown in Fig.1.

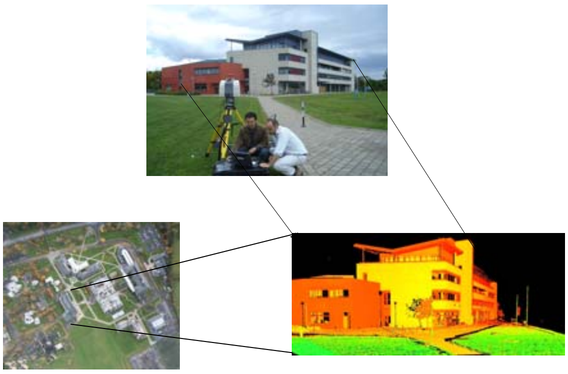
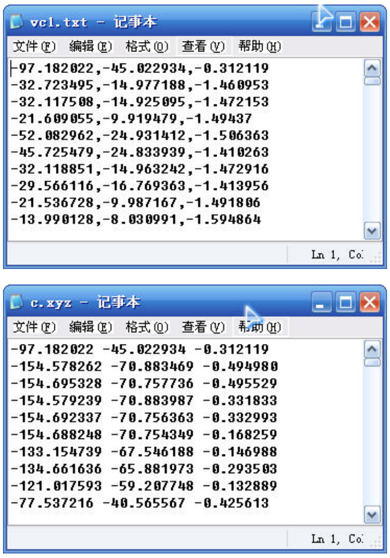


Fig.1 field and raw LiDAR data collected

The raw LiDAR data showed in Fig.1 was visualized by Leica cyclone5.8, which provides integrated LiDAR data processing environment. This image is one scanworld of the whole survey data. Each scanworld includes the LiDAR data acquired from one spot. The data format is *.imp. Cyclone doesn't provide functions of automatic linear feature extraction and edge detection, though it has manual edge detection function. The raw LiDAR data have to transform into other formats, which could be read by other software, for realizing edge detection and linear feature extraction. Fortunately, cyclone can export scanworld into several formats, which are widely used, such as DXF, xyz and txt. Different format contains the same X, Y, Z coordinates of base spot and those of objects. However, the points are recorded in various orders in different formats. For example, Fig.2 shows the difference order.



vc1.txt - 记事本

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-21.609055,-9.919479,-1.49437
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-32.118851,-14.963242,-1.472916
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Ln 1, Co

c.xyz - 记事本

文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)

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-154.579239 -70.883987 -0.331833
-154.692337 -70.756363 -0.332993
-154.688248 -70.754349 -0.168259
-133.154739 -67.546188 -0.146988
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-121.017593 -59.207748 -0.132889
-77.537216 -40.565567 -0.425613
```

Ln 1, Co

Fig.2 difference order of coordinates in various formats

The first records in the two files are the same. They are the value of base point. This show the points are recorded without definite order. This causes some difficulties in data processing.

Lidar data are also different from raster image. They are vectors. And they have real 3D information. As to raster image, parameter Z stands for grey value of a grid. This means raster image is not true 3D. Most tradition edge detection algorithms for raster image are usually not suitable for Lidar data.

3. ALGORITHM FOR EDGE DETECTION OF TERRESTRIAL LIDAR DATA

The key step to realize linear feature extraction is edge detection. Since terrestrial LiDAR data has different characters from raster image and airborne LiDAR data, it is necessary to build effective and efficient algorithms to realize edge detection. Some researches have put forward results of traditional algorithms in edge detecting of LiDAR data, such as Sobel, Kirsch, LOG, Canny and Roberts operators (Li Qi, 2003; .Lai Xudong, 2005). These algorithms were demonstrated not suitable for edge detection of LiDAR data. Zheng (2005) used fractal dimension methods to distinguish road from river in IKONOS image. Studies show that the nature background in the image is accorded with Brown movement model, which shows self-comparability of its local gray, some relativity with less variety of grey-level between neighbor pixel. On the contrast, the man-made objects have the brims with grey breaks and relative grey varieties between neighbor brim pixels (Yang, 2003). With the slide window, in nature background, its fractal dimension is small. If more brims of man-made objects, its fractal dimension is bigger. Since the nature and man-made objects have different fractal dimensions generally, Zheng (2005) demonstrated fractal dimension theory can be used distinguish road from river element from remote sensing images automatically. The research gave illumination to edge detecting of terrestrial LiDAR data. If there is an edge, fractal dimension of the grid that it belongs to must has bigger value than that of inner grid. Since LiDAR data the different features, the algorithm used in Zheng's research has possibility to be used for edge detection of terrestrial LiDAR data.

In general, fractal dimension theory mainly has three algorithms, line-divider method, slop-direction method and Triangular method. This research chose the third one for its advantages. Triangular method is same in nature as the slop direction one. The fractal dimension can be obtained by calculating the 3D surface area of the remote sensing image. However, the algorithm is more precise. The study shows: the nature background is accorded with fraction Brown movement model, which is one of the classical models in fractal signals (or image) study for its excellent characters. By the way, the surface area is measured by the following equations (Zheng, 2005) :

$$\log A = C + B \log G \quad (1)$$

$$D = 2 - B \quad (2)$$

Parameter A stands for the measured surface area，G is the step, B is the slope, C is a constant, and D is the fractal dimension. Due to no entire self-similarity, it often shows the similarity from the statistic extent. In practice, a series of G and A values are selected in the logarithm coordinate system and are fit with use least-square method. The fit-line slope is parameter B. With formula 2, he fractal dimension D, can be calculated out.

According to the characters of fractal curved surface, the bigger the step for calculating the area of curved surface, the smaller the area of the curved surface. So the slope value of fitting curve is a negative number and the fractal dimension, parameter D, is between 2.0 and 3.0. This is accorded with fractal theory. The principle of triangular method is shown as Fig.3 (Zheng, 2005).

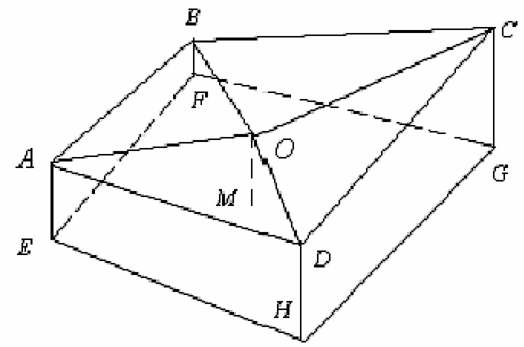

Fig.3 the principal of triangular method

A grid formed by E, F, G and H, and their grey-level are named as $P_{A,}P_{B,}P_C$, and P_D. The grey-level of the grid central is P_O. It can be calculated by the formula (3).

$$P_O = (P_A + P_B + P_C + P_D) / 4 \qquad (3)$$

The curved surface area ABCDO is worked out by triangular formula. Then, a series of areas are calculated with specified steps. Selecting the step values as 1, 2, 4, 8 …… (The integer power of 2) in turn, we can get the 3D areas. With least-square method, double logarithm-fitting and formula (2) can to work out the fractal dimension of the remote sensing image.

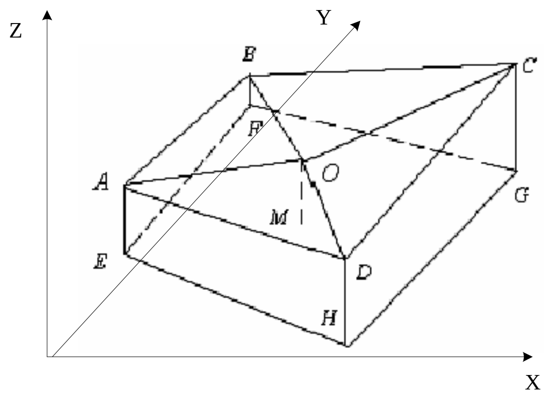

Fig.4 improved triangular method for edge detection of terrestrial LiDAR data

In Fig. 3, points of E, F, G and H are the four corner of a raster grid, with grey value of the points formed their new position, points of A, B, C and D. As to terrestrial LiDAR data, the points of A, B, C and D in Fig. 4 are real 3D vectors. So it has coordinates system. Its original point is the basic point of the scanworld of LiDAR data. And formula (3) should be modified as formula (4) for one grid may contain a number of points.

$$P_O = (P_A + P_B + P_C + P_D + \ldots\ldots + P_n) / n \qquad (4)$$

n stands for the number of points in the grid. Then it calculates the fractal dimension values of grids. There are some basic rules for automatic judgments.

- If the fractal dimension values of adjacent grids are close, then there are no edges contained in the grids.
- If the fractal dimension value of one grid is different from one of adjacent grids, it or the adjacent grid contains edge.
- If the target grid has two adjacent grids with different fractal dimension value, and the two adjacent grids are not opposite side, there is corner point in one of the grid.

Corner grid	Adjacent grid	Corner grid
Adjacent grid	Target grid	Adjacent grid
Corner grid	Adjacent grid	Corner grid

Fig.5 target grid and adjacent grids

Then how to determine which point in which grid lie on the edge is a problem. It can be solved by quad tree methods. It means to divide related grid by quad tree and go back to carry out procedure from the beginning until it can't be divided and found the edge points.

After we obtain edge points, it links the neighbor points. Then calculate the slope of the line. If the slope of the line has distinct changed, the last point should be corner point. The thresholds of this judgment and that of different fractal dimension value rely on experience. The calculation can be easily conducted by Matlab.

4. PROCEDURE OF LINEAR FEATURE EXTRACTION

Before edge detection of terrestrial LiDAR data, some pre-processing measures should be carried out.

- First, interference should be segmented from target data. Main interferences are trees and cars in front of building. As mentioned above, Fractal dimension theory provided effective way to distinguish man-made objects from nature ones. Here the research can use it to fulfill the task.
- Second is to determine the size of grid. If grid size is very small, it will increase the computing volume. On the other hand, if the size is very big, this may make it easy to miss real edges because large sum of points in grid may make the fractal dimension values much closer, which would cause incorrect judgments.
- Third is to obtain reasonable thresholds for edge detection and corner point's judgment. And when the raw terrestrial

LiDAR data were read, remember the data were recorded disorderly.

- Then it goes to calculate for edge detection and obtain edge and corner points by automatic judgments.
- Isolating individual building objects.
- Rebuilding the buildings by the linear features.
- Evaluating by field survey.

5. CONCLUSION

This research is initial work carried out at the National Centre for Geocomputation Ireland for virtual campus building. Its aim is to set up effective and efficient algorithm for edge detection and make technique route to realize linear feature extraction from terrestrial LiDAR data. There still have much work to go further. The research put forward fractal dimension method for edge detection. It will be demonstrated with field terrestrial LiDAR data in the near future.

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