Feature Extraction And Modeling Of Urban Building From Vehicle-Borne Laser Scanning Data

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ABSTRACT:

Laser scanning is playing an important role in an acquisition of the 3D spatial objects in urban because of real-time and high efficiency than traditional methods. The research presented in this paper is focused on segmentation of range image, especially captured by vehicle-borne laser scanning systems, which is the crucial technology for extracting objects from laser scanned data. Here, a method, named as Density of Projected Points (DoPP) is proposed for the range image segmentation. With such a process, it is possible for feature extraction, object classification and modeling without other auxiliary data. An experimental study is conducted to demonstrated the feasibility of the proposed solution on urban building object extraction.

1. INTRODUCTION

Geo-spatial information technology is one of the focuses of research of worldwide countries nowadays, and the acquisition, processing and application of information are the three themes. The technology of high speed acquisition and automatic processing of spatial data is a crux need to be solved urgently in the field of Digital Earth. In the late 1980s, laser-scanning technology gained important improvement in the real-time capture of 3D spatial information, which provided an option for the acquisition of high resolution spatial information, and enabled people to capture data moving from point by point traditionally to continuous automatically. Laser-scanning survey technology is not restricted by weather, and it directly captures high precision 3D data in uncontacted active survey way. It has superiority which tranditional survey technology cannot substitute,and it has been developed as an important supplement of photogrammetry and remote sensing.

Based on the difference of mounting platforms, laser-scanning systems were classified into Airborne Laser Scanning System (ALSS; also called Laser Range Finder, LRF; or Airborne Laser Terrain Mapper, ALTM) [Flood 1997, Killian 1996] and Ground-based Laser Scanning System (GLSS; or Vehicle-borne Laser Mapping System, VLMS) [Li 2000,Li 2003].

ALSS is a multi-sensor integrated complex system, and it has been gradually matured [Ackermann 1999]. Currently in the world there are some systems as follows: the TopEye system from the Saab Survey in Sweden, ALTMS from Optech in Canada, the Fli-Map developed in the U.S. by John E. Chance, and TopSys and TopScan from Germany. Airborne laser-scanning technology has extensive application in surveys of sagging power lines [Wehr 1999], and surveys of coastlines and forests [Kraus 1998], mine fields, and urban areas [Kraus 1998, Erik 1997, Haala 1997, Murakami 1998].

The products and application of the GLSS for data capture are still at developing stage. Based on the style of data capture, it can be divided into both static-scanning and mobile-scanning. The typical product of static-scanning is the Cyrax serials from Leica. Mobile scanning system such as the sample vehicle developed by Tokyo University [Manandhar 2001], which consists of three laser scanners and six line cameras, is mainly applied in the data capture and modeling of city buildings and roads. Hi-Tech Research and Development Program of China (Project 863) has successively funded vehicle-borne laser-scanning survey technology [Lu 2003].

Data captured by laser scanning are called “Range Image” or “Points cloud” which consists of discrete vector points. The range image captured by close-range and high-resolution consists of abundant features: both topographic and ground objects information. So it is possible for us to extract feature according to height information besides constructing high-quality DEM directly [Weidner 1996, Brunn 1997]. Because the range image consists of discrete points, without topological relation, boundary attribute and object feature, it brings about the uncertainty of extracted object. The key to the problem focuses on how to distinguish different objects and construct model respectively. Manandhar (2001) has classified scanning points according to the spatial distribution feature of laser points in each scan line. Although the data processing is complex, it can separate buildings, roads and trees etc. Li (2003) researched linear building feature extraction from range images. But all those are limited in extracting only one lateral feature of buildings. Because hitherto there are no matured feasible methods of segmentation and feature extraction from range image, current laser-scanning systems are all integrated with CCD or similar image acquisition devices. The range images are mainly used as a supplement of photogrammetry or be constructed high-quality DEM/DSM, and the CCD image data for image segmentation and feature extraction [Ackermann 1999]. This collaborative mode has the character with the high cost of time, the large quantities of data-storage and the complex processing and integration of multi-source data. Segmentation is the base of identification, location and modeling of objects. This paper mainly researches the technology and method of segmentation and extraction from range images captured by vehicle-borne laser scanning system.

2. WORKFLOW OF OBJECT ACQUISITION AND SEGMENTATION

2. 1 Acquisition Of Range Image

Vehicle-borne laser scanning system realizes the combination of multi-sensors such as 2D Laser Scanner, GPS, attitude-measure device (IMU, INS or multi-antenna GPS) and Odometer onto the automobile platform. Under the control of the vehicle-borne computer, the automobile runs along building at the normal speed (Fig.1), the surface geometric information of the objects is acquired in the real-time. In the system, GPS gives the precise 3D position of the LS in the space, attitude-measure device gives the attitude parameter of the LS in the space, and laser scanner precisely determines the distance from the scanner center to the object at high frequency. According to geometry theory, the 3D coordinates of the sampling points can be calculated to form points cloud easily and quickly.

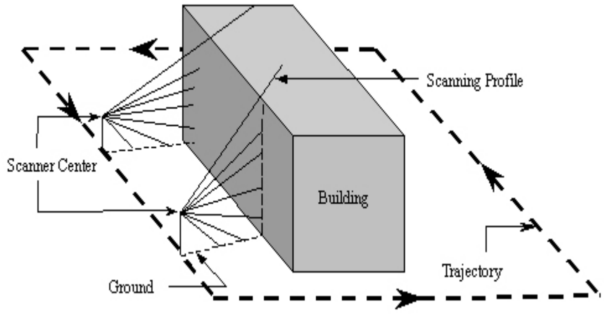


Figure 1: The principle of scanning a building object and other visible objects around the building

2.2 Principles and Workflow Of Data Processing

Image segmentation is one kind of fundamental technology of computer vision and image analysis. To 2D grey image, the procedure for image segmentation is to classify the image into distinct groups and to extract the interested groups or objects from image. From 1960s plenty of researches have been done on grey image segmentation and formed about 1000 kinds of segmentation algorithms [Pal 1993]. Most of algorithms are aim at special problem and there is not suitable for all images. Even given a practical case of image segmentation, there is no standard for selecting suitable segmentation algorithm [Zhang 1996]. Usually some important features are selected to make the main objects of image achieve the best and the most marked, at the same time discard the irrespective or minor information in order to reduce the complexity of classification [Vailaya 2001].

Range image represents the surface geographic information of the objects in the form of 3D discrete coordinates, which has no description of attribute and there does not exist topological relation among the data points. Compared with normal 2D grey image, range image does not exist visible boundary or the possibility of “see” the objects. Current algorithms for image segmentation and identification are all aiming at 2D grey image, which cannot be used for the classification of 3D range image. This paper presents the segmentation method of different objects (buildings, roads, trees, independent objects such as lamp-pole etc.) from range images through the spatial feature analysis of the objects. The principle of object segmentation is: 1) to form horizontal mesh grids; 2) to project all the data points on the grids and calculate the number of points of each grid unit, in this paper we call it Density of Projected Points (DoPP); 3) to regard DoPP as the basis of objects classification. According to the difference of DoPP, sometimes need additional height-information, different objects can be distinguished. The operational workflow of data processing is shown in Fig. 2.

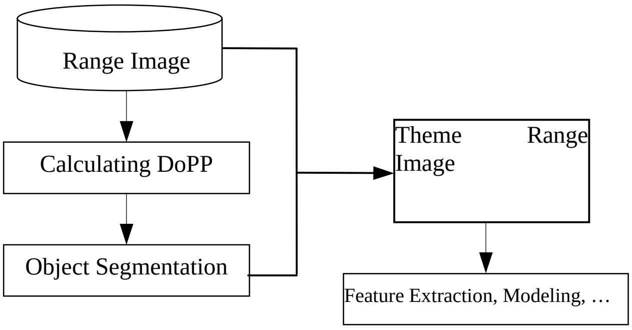


Fig.2 Workflow of Data Processing

3. SPATIAL FEATURE AND SEGMENTATION OF RANGE IMAGE

3.1 Spatial Feature Analysis Of Different Objects

Range images consist of objects such as buildings, ground, trees, vehicles, lamp-poles, pedestrians etc. Our research in this paper is focused on the object segmentation and feature extraction of the important objects such as buildings, ground and independent objects such as lamp poles etc.

As Fig. 1 shows, all targets in the field of view of the scanner can reflect laser to get “image-point”. On one hand, data collection has somehow blindness or uncertainty, so it is not certain to obtain feature of ground objects and terrain, and the automated identification of objects is very difficult; On the other hand, there has discreteness in the points on the same scan line and divergence between adjacent points which makes data processing very complex. In the following we analyze the spatial feature of different objects.

3.1.1 Spatial Feature Of Ground Points: Range image as shown in Fig. 3 consists of plenty of topographic points. The topographic points usually are smoother and the height value is relatively smaller and the variation in height value is not big. The distribution of topographic points on the horizontal plan is irregular. The sampling points on each unit area accord with a certain rule: There are many points near the scanner. The farer distance from the scanner, the less points.

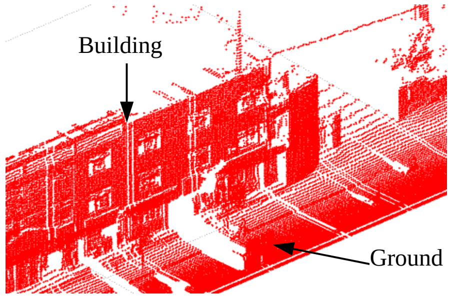


Fig.3 Points cloud of a building

3.1.2 Spatial Feature Of Independent Object: Independent objects such as trees and lamp-poles, with a certain height and area range, which are higher than surrounding topographic points and the sampling frequency of local units on horizontal plan is high. As shown in Fig. 4.

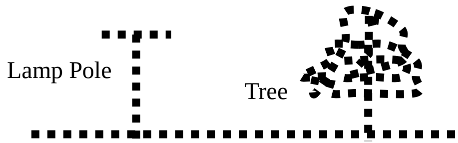


Fig.4 Sampling independent objects

3.1.3 Spatial Feature Of Building Points: Without lost universality, we can consider the buildings are higher than surrounding terrain and their walls are vertical. There are plenty of sampling points from the building surface and the sampling frequency of the horizontal outlines of the building is high. And on the same scanning line, the deviation between adjacent points is very small in X and Y directions and there has an approximately vertical direction vector in Z direction.

3.2 Principles And Method Of DoPP

According to the spatial feature analysis of points, we propose the method of DoPP below (see equation 1).

$$DoPP = \mathrm{int}\left(\frac{ATN(H/D)}{\alpha}\right) \tag{1}$$

Here, the value of *DoPP* is dependent on the target’s height (H), distance from the scanner to the target (D), and on the resolution of the scanner (α).

To simplify the calculation, firstly we can divide surveying region into regular mesh grids, then project all points into horizontal plane by equation 2,

$$
\begin{bmatrix} X & Y & 0 \end{bmatrix} = \begin{bmatrix} X & Y & Z \end{bmatrix} \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix} \qquad (2)
$$

And then calculate the quantity of projected points of each grid; regard the number value as the *DoPP* of that grid. So the *DoPP* can be presented discretely. According to the definition above, we can calculate the value of *DoPP* of each grid if we select reasonable grid size, for example, form grids according to the sampling interval designed by scanning system. And the value of *DoPP* has feature as follows (see Fig. 5):

1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
1	4	6	1	1	1	1	1	1							1	1
1	5	3	1	1						0	0	0	0		1	1
1						0	0	0	0	0	0	0	0		1	1
1			0	0	0	0	0	0	0	0	0	0	0		1	1
1	1		0	0	0	0	0	0	0	0	0	0			1	1
1	1		0	0	0	0	0	0						1	1	1
1	1		0	0						1	1	1	1	1	1	1
1	1					2	1	1	1	1	1	1	1	1	5	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 5: DoPP on a horizontal mesh grid with a building and other objects

- DoPP has a smaller value and is evenly distributed on the surface of the ground;
- DoPP obviously has a higher value along the boundary of the building (the gray band in Fig.5) than in other regions, and form continuous band;
- The DoPP in the inside region of the building is equal to zero if without the effect of noise points;
- The DoPP of an independent object such as lamp pole is greater than that of surroundings objects.

With use of the above knowledge, select reasonable thresholds T_1, T_2, object segmentation can be carried out according to formula 3:

$$
DoPP \cdots \begin{cases} > T_1 & building \\ < T_2 & ground \\ else & else \quad objects \end{cases} \qquad (3)
$$

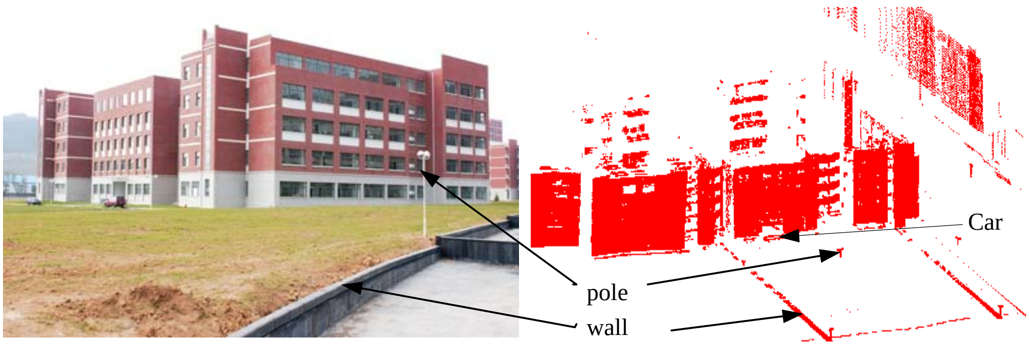
Thresholds T1, T2 are determined by formula 2 according to practical condition and the purpose of data processing. After segmentation, we can get the range images of ground, of buildings and of other objects. The data processing, feature extraction and modeling, visualization for theme image are much easier than for original range image. Especially segmented buildings, feature extraction of building's surface outline based on the segmented image can be realized, and the vertical feature of building through further combination with the value of Z can be reconstructed.

4. Experimental Study

Two experimental studies were carried out to demonstrate the feasibility of the above-proposed method of segmenting different objects and of extracting urban building objects. The operational workflow for processing range image data is as follows: 1) Form a grid mesh with grid size of 0.1m×0.1m to the surveying region; 2) Project all the points in the range image onto the grid and calculate the *DoPP* for each grid; 3) Select reasonable *DoPP* threshold to segment the original range image and get the special topic range image.

4.1 Case 1

Fig. 6b is the special range image formed by getting rid of ground points from the original range image (Fig. 6a), which preserves the targets with certain height. Building can be extracted and rebuilt by using the height value information of points.



(a) (b)

Fig. 6 a) Image for testing building; b) Range image as *DoPP*>10

4.2 case 2

Fig. 7 shows the points cloud of another building, which consists of 3050 thousands points. Fig. 8 is the projection of the building onto horizontal plane. With the condition of DoPP >=30, an useful result is obtained and is illustrated in Fig. 9, where 23 000 raster grid points are used and a narrow valid region is generated. The stochastic noise into the building are all together thrown off; The horizontal outline of the building can be obtained by further linear feature extraction and figure structure edition, see Fig. 10, and the 3D model of building with the height information of building can be rebuilt. Fig. 11 shows the result with average height of the building.

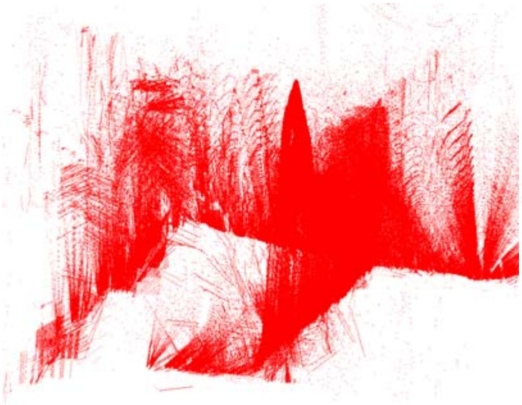


Fig.7 3D range image of building

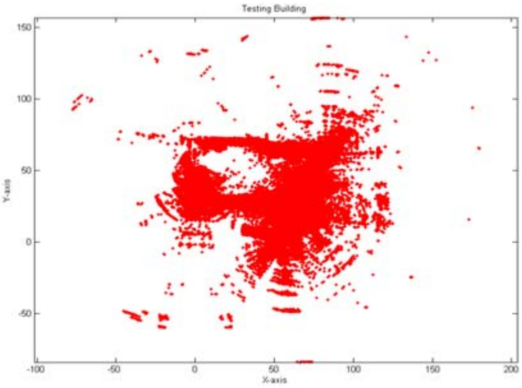


Fig. 8 Horizontal projection map

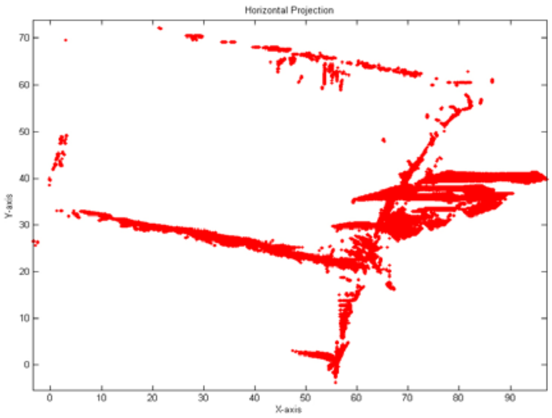


Fig9 Projection to horizontal plane as *DoPP* >=30

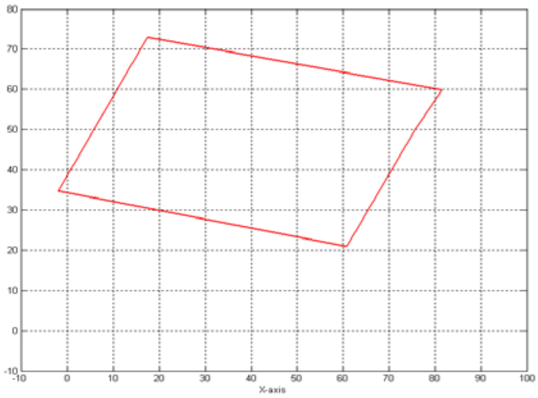


Fig. 10 Result of analyses and interactive editing

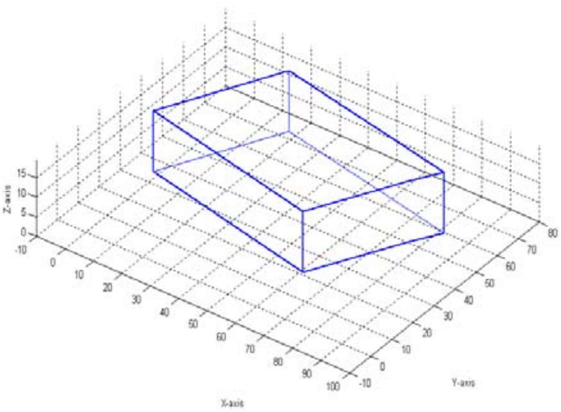


Fig. 11 3D Model of Building

5. CONCLUSIONS AND FURTHER RESEARCH

The vehicle-based laser scanning system is a new technology for quick acquisition of 3D information. Ground targets, such as urban buildings can be extracted from laser-scanned data. One of the most critical issues for the application of this laser-scanning technology is the development of efficient methods for extracting and reconstructing objects from the huge amount of laser-scanned data.

This paper presented a research development on the extraction of urban buildings from vehicle-borne laser-scanning data. An operational workflow of the solution was proposed. With auxiliary height value, various important objects in the range image are differentiated and feature extraction, 3D reconstruction and visualization can be realized with further processing.

Further research along this line may include, for example, improving the reliability of the algorithms to handle the extraction of complex objects; developing a user interface to facilitate the use of semi-automatic editing process when the use of an automatic process is problematic; to detect detailed structures of a building; to assess the accuracy of the detected details; and to integrate such data with other sources such as multi-spectral images or GIS data to reconstruct objects.

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