APPLICATION AND PRECISION ANALYSES OF AIRBORNE LIDAR TECHNIQUE IN ZHEJIANG AREA

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ABSTRACT:

This article presents the application research of airborne LIDAR (LIght Detection And Ranging) and accuracy analyses in southern part of China. First, the increasing demand of LIDAR and its principles shall be introduced. Second, the main LIDAR data processing flow will be described briefly. Third, the concepts and experiment conclusion of a new filtering method are recommended. And then, the precision evaluations in the test site are presented.

1. INTRODUCTION

The requirement for precise Digital Terrain Model in producing the stereo images have been a time and cost consuming task for all the image processing work (Lillesabd and Kiefer, 1999). How to acquire spatial information with good rate, high accuracy and excellent reliability turns into a significant position in geographical information which is one of the particular uses requiring much dense Digital Terrain Model grid.

As a tool for rapid topographic feature extraction, LIDAR is an active remote sensing technique that measures the range to and the reflectance of objects on the earth surface, thanks to the accuracy and density of the 3D data (Figure 1). This system basically consists of GPS (Globe Positioning System), IMU (Inertial Measurement Unit), laser scanner and powerful PCs for data processing. Some photogrammetrists say that LIDAR has caused a paradigm in photogrammetry because of its big impact on methods like DTM generation or 3-D city model reconstruction. This paper mainly presents application in southern part of China with LIDAR technology including key methods of digital terrain model extraction and accuracy analyses.

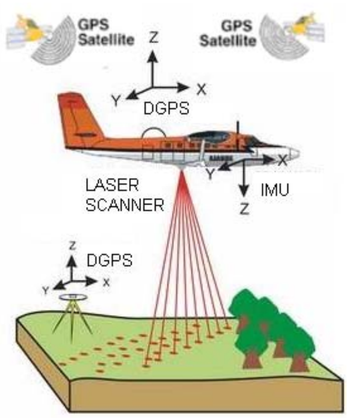

Figure 1. Airborne-LIDAR system principle

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2. LIDAR DATA PROCESSING FLOW FRAME

The original data obtained by Airborne LIDAR includes laser data, GPS data, IMU data (some calls INS data, Inertial Navigation System data) and digital images (optional). After being solved by several particular software, they can output kinds of products of surveying and remote sensing. The flow of LIDAR data processing from laser data collection to production output can be concluded to data collection, data pre-processing, filtering and classification of LIDAR point, fusion and application of LIDAR and other remote sensing data. The particular working procedure is showed in the figure below..

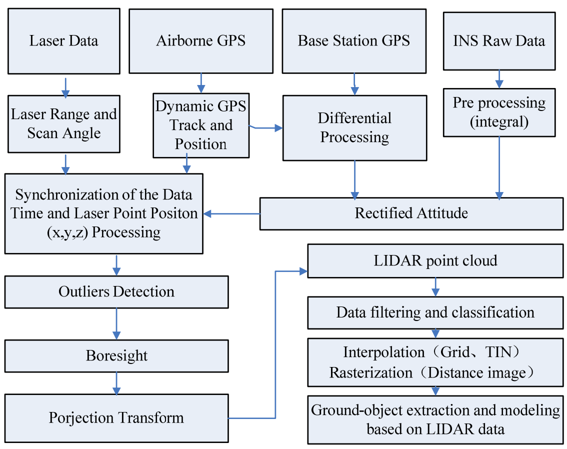

Figure 2. The flow of LIDAR data processing. (Zhang Xiaohong, 2007)

3. DIGITAL TERRAIN MODEL EXTRATION

As a important part of laser data processing, filtering and classification influence the efficiency and effect of the digital terrain model extraction. The laser pulses reflected on the ground surface need to be distinguished from those reflected on buildings, vegetation and abnormal points. Every filter makes an assumption
about the structure of bare earth points in a local neighbourhood.

A considerable number of algorithms have been created to filter LIDAR points without other assistant of data. Kraus and Pfeifer (1998) filtered LIDAR data for forest areas using an iterative, linear least squares interpolation method. Axelsson (2000) developed an adaptive Triangulated Irregular Network (TIN) method to find ground points based on selected seed ground measurements. Elmqvist (2001; 2002) classified ground and non-ground measurements based on active contours. Sithole (2001) reduced omission errors occurring around steep ground features by adjusting slope factor adaptively according to local slopes of a preliminarily produced surface. Although there are such methods for filtering, the adaptability and precision of these algorithms in different areas still cause problems. It is said that classifying or filtering laser points only based on laser data has difficulties with regard to blindness.

3.1 Principle and Presume of the Algorithm

In this paper, a new method is proposed for filtering airborne laser points. In this algorithm, laser points are filtered in according to the given DTM. Corresponding coordinate information and characteristics of terrain are used to match different data and determine the effective areas of the LIDAR points and other kinds of information. When the slope of the laser points is in the original buffer zone, the point keeps to the ground type (or class) which is represented as DEM in the equation (1) which is based on the set theory. By contrary, it keeps to the nonground type.

$$\begin{aligned} DEM = \{ & p_i \in A \mid \forall p_j \in A : \\ & h_i - h_j \le \Delta h_i \left(d(p_i^* - p_j^*) \right) \} \end{aligned} \tag{1}$$

The given DTM points or DTM surface model create the original optional slopes. The slopes depend on the neighbouring elevation and distance. B is an active window for calculation.

$$\begin{aligned} \Delta h_i = \Bigg\{ & f\left(\frac{h_i^*}{d(p_i^* - p_j^*)} \times B \right) \Box d_{i,j} \mid \\ & h_i^* \in A^* : \forall h_j^* \in A^*, m = 0,1,2 \Bigg\} \end{aligned} \tag{2}$$

$$p_i = \{ \min(p_i) \mid \forall p_j \in A^* \} \tag{3}$$

$$f(x) = \sqrt{\frac{\sum_{i=0}^{n} \left(x_i - f_1(x) \right)^2}{n-1}} \tag{4}$$

The width of the buffer changed in iterative process. Several features of topography and LIDAR raw data are taken into account, including the diversity and complexity of buildings, density of vegetation, slopes, noise information in the height information of LIDAR data. Given DTM provides the original optional slopes, which help to find the optimal kernel function.

3.2 Test Datasets and Results

Several experiments have been performed to test the behaviour of the multi-data filter method, including urban areas with low-relief topography and forest areas with high-relief topography. The test site is located in the downtown of Yongjia in Zhejiang province in China and covers about 5 km2. The dataset was collected by a Leica ALS50Ⅱ LIDAR mapping system mounted to a Yun-5 aircraft in early spring 2008. By flying at a relative altitude of 1900 meters, we collected approximately 2 meters laser spacing of range data. The given DEM datasets was produced in 1990s by means of traditional photogrammetry of 1:10,000.

From the results images, especially the shaded relief map (Figure 3), it can be found that the filter algorithm removed most of the nonground objects successfully in urban area, but the points at the edge of building and canal remains, and some ground points were filtered out mistakenly. The original points is from 13.84 to 89.24 meters and 34% of the points is classified to ground.

At the mountainous area, Figure 4 shows the shaded relief maps for the grids generated from filtered LIDAR data using TIN. 61% of the data is filtered to ground points which have some of the nonground measurements remain because laser pulses were reflected by the canopy and did not reach the ground. The elevation changes and slope factors of some tree tops are similar to those of low topographic relief.

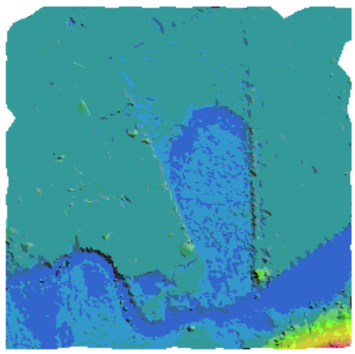

Figure 3. Shaded relief maps for the TIN generated from filtered LIDAR data

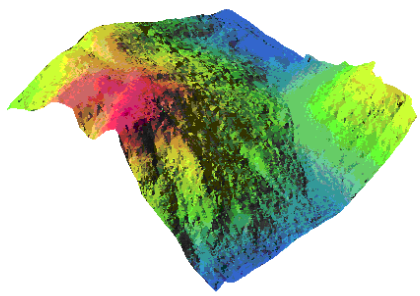

Figure.4. 3D-view of filtered laser data

In the basis of the shaded relief maps analyses above, a method of quantitative analysis is used in this paper. All the filtering algorithms examined make a separation between object (nonground points) and bare earth (ground points) based on the assumption that certain structures are associated with the former and others with the latter (George Sithole, George Vosselman2003). There are Type I and Type II errors in laser information extraction, on purpose of determining the potential influence on the filtering algorithms on the resulting DEM, based on the predominant features in the data set. Type I means classifying bare earth points as object points, on the other hand Type II errors imply classifying object points to bare earth points.

Three hundred reference points are selected in each test area, with half points as objects points, and the other half from bare earth. From the filtering results (Table 1), 80 percent of the points are successfully recognized in every sort. Type I Errors are always bigger than type II, by reason of the algorithm is designed for marking bare earth points as far as possible to object.

Test Site	Reference Points	After filtering		Statistic	
		Ground	Nonground		
1	Ground Points	127	23	Type I Error（%）	15.3
	Nonground Points	4	146	Type II Error（%）	2.6
2	Ground Points	132	18	Type I Error（%）	12
	Nonground Points	11	139	Type II Error（%）	7.3

Table 1. Filtering Results

4. ELEVATION ACCURACY CHECKING

As a new technology, users pay more attention to the stability and precision of the surveying results. We examined the test site's LIDAR data by RTK (with one base station and several mobile stations) technology.

Getting rid of one blunder point G36, the evaluation of the laser points as follows. Mean square error of the points is 0.22 meters. 106 check points' elevation differences are within ±0.4 meters accounting for 92％ of the total points, 47 points' elevation differences are between ±0.2 and ±0.4 meters accounting for 41％, 59 points' elevation differences are within ±0.2 meters accounting for 92％. There are 5 points two times larger than the mean square error, accounting for 3.9% of the total points, meeting the error requirement.

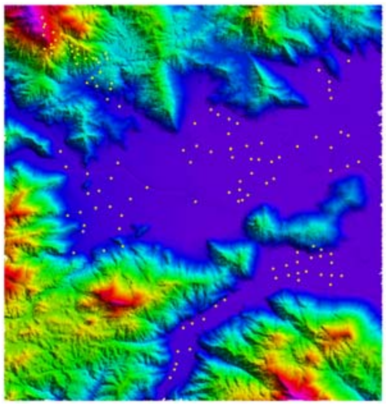

Figure 5. The sketch map of check points (127 points in 300 km^2 areas with different topography)

Point No	X	Y	Known Z	Laser Z	dZ
	m	m	m	m	m
G99	270666.402	3116109.369	19.508	19.5	-0.008
G123	270503.564	3116050.389	20.287	20.28	-0.007
G1	272338.532	3116089.509	19.095	19.09	-0.005
G27	269538.018	3117264.538	162.606	162.64	0.034
G82	272462.259	3116274.8	18.686	18.74	0.054
G50	271236.707	3115428.896	18.591	18.71	0.119
G94	270394.889	3113322.502	30.019	30.14	0.121
G7	272155.535	3116216.148	17.991	18.18	0.189
G9	271064.622	3116259.882	17.283	17.48	0.197
G33	268981.447	3116035.567	32.451	32.65	0.199
G119	271173.178	3116385.236	19.638	19.84	0.202
G125	269609.362	3115703.518	26.904	27.12	0.216

Table 2. Part of LIDAR points accuracy results (the result value is in UTM Projection, geodetic elevation; known z means check points elevation value, laser z means DEM elevation)

Type of points	Quantity. of points	Percent	Max	Min	Mean value	Standard deviation	Mean Square Error
		%	m	m	m	m	m
Total Points:	126	—	—	—	-0.03	0.22	0.22
>40cm:	9	7.14	0.769	0.412	-0.14	0.57	0.55
>20cm & <40cm	33	26.19	0.376	0.2	-0.03	0.27	0.27
<20cm	84	66.67	0.191	0.003	0.08	0.10	0.12

Table 3. Laser points evaluation

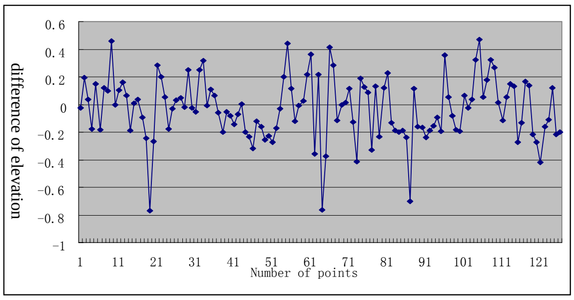

Figure 6. Graph of elevation difference

5. CONCLUSION

This paper presents the application of laser scanning technology in Zhejiang province. A new multiple data filter method with LIDAR points and given DEM data is proposed, that classifying ground points with other kinds of data is effective, especially for the vegetation areas. However, some of the characteristics of the landscape and data are difficult for this method, which lead to further research. Airborne LIDAR technology is a good method for acquiring accurate digital terrain model data on the basis of the precision analyses.

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