EXPERIMENT OF ESTIMATING FOREST STAND VOLUME WITH LIDAR TECHNOLOGY

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ABSTRACT:

In this paper, LiDAR was introduced in tree height and stand volume measure. By experiment, the average of trees' height was 8.68 meter measured by LIDAR, while the actual value was 8.67; the relative error between them was 0.913% which showed positive correlation. Then we fitted the relationship of tree height and stand volume with different coefficient methods. From quadratic polynomial to six polynomial fitting results, the correlation coefficient changed slightly from the polynomial index increased by four. At last, we can drew that estimating forest stand volume with LIDAR technology can save amount of field work time and improve the work efficiency. It meets the requirement of forestry survey measuring. The reasons for that there was error and exceed error by use of LiDAR for height measurement, were also discussed.

1. INTRODUCTION

LiDAR (Light Detection And Ranging) is airborne laser detection and ranging system installed on the plane. By three-dimensional coordinate measurement of ground objects, the LIDAR collects images data. The system integrates the Laser Ranging technology, GPS technology and inertial navigation technology IMU, its initial purpose is to obtain high-precision digital surface model DSM (Digital Surface Model) (LI Ying cheng, 2002). At present, most LiDAR system can record multiple echo (at least in general more than two), which is top, bottom and anywhere position information. Each echo records the same three-dimensional coordinates (FENG Si liang, 2005). As LiDAR with high angle-resolved, distance-resolved and anti-interference advantages, it make laser radar can access information the height of surface objects with high-precision. In general terrain conditions, the plane accuracy of in LiDAR is between 0.5 to 0.7 meters, the vertical accuracy can be decimeter (LIAO, 2004).

In most forestry applications, LiDAR systems sample interval spot less than 1 m (PANG Yong, 2005). The actual acquired data by the laser was detected "point cloud" of objects. In general, each tree requires a few to hundreds of laser Echo, from this point cloud trees parameters can be estimated (WU Hua yi, 2006; J. Holmegren, 2004). There is large number of references abroad has showed successful application in forestry. In the forestry practices, we always get the DOM (Digital Ortho-photo Map) images and point cloud images, stacking these two layers we can get the 3D (three dimensional) effect graph. And then, we will obtain the measuring points' elevation. According to this feature, we can obtain tree height (DENG, 2005). Thus, LIDAR technology can be used in the study of estimating forest Stand Volume.

2. EXPERIMENT

2.1 Tree height by real measure and by LiDAR

In LiDAR experiment, district of LiDAR data is located in northwest of Changping district, Beijing. For flight equipment, laser scanner rangefinder ALTM3100 from Optech in Canada company is selected, including four echo data. In order to position the trees' location, we also corrected the true color aerial photo by digital cameras ALTM4k-02 in LiDAR equipment. The LiDAR point cloud data was read by iLidar software (iLiDAR User Manual). In addition, noise of the point cloud need to be processed and classified. Height measurements are processed using laser radar software Terra-Solid from Netherlands.

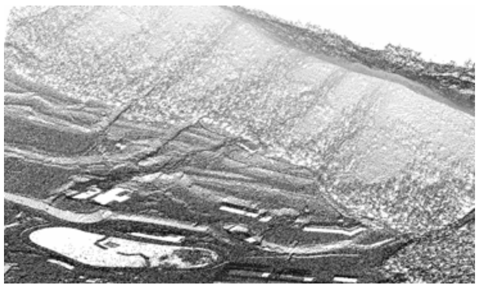

Figure 1 Three dimensional result of LiDAR cloud point

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Figure 2 Three dimensional result of LiDAR cloud point added with DOM

By image and field interpretation, the LiDAR experiment area includes about 0.5 hectares of woodland, the main types of trees is *sabina virginiana*. In Orthophoto image, 37 representative trees were chose for materials. Firstly, these point cloud need to be classified after filtering the noise elevation, then were measured by TerraSolid software in View Laser module. The tree height measure was carried out by directly measuring the vertical distance between the top of tree and the base of tree in LiDAR data (see Figure 3). At the same time, by Total Station, we measured 37 tree heights, got the result and error of measurement

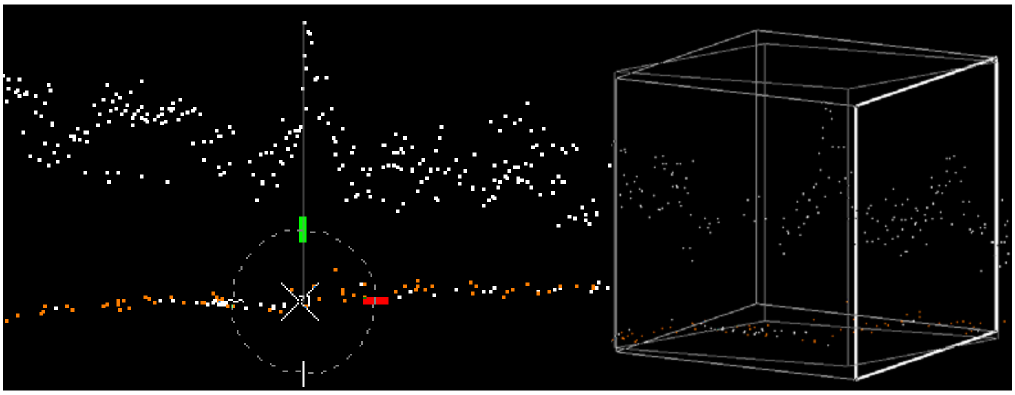

Figure 3, 4 Indoor work of Forest height measuarement with LiDAR

No	Tree height by Lidar /m	Real Tree height /m	Height difference /m	5% error bounds /±m	Real volume /m³	No	Tree height by Lidar /m	Real Tree height /m	Height difference /m	5% error bounds /±m	Real volume /m³
1	9.39	9.12	-0.27	0.46	0.1215546	20	7.39	7.37	-0.02	0.37	0.0267265
2	10.01	9.87	-0.14	0.49	0.080068	21	5.67	5.47	-0.20	0.27	0.0223637
3	5.68	5.88	0.20	0.29	0.0301406	22	7.47	7.85	0.38	0.39	0.0332041
4	7.97	8.20	0.23	0.41	0.0345693	23	3.97	3.69	-0.28	0.18	
5	8.04	8.50	0.46	0.43	0.0433328	24	5.77	5.91	0.14	0.30	0.0335426
6	9.47	9.10	-0.37	0.46	0.0861335	25	6.16	5.89	-0.26	0.29	0.036087
7	9.00	9.04	0.04	0.45	0.0615592	26	4.59	4.68	0.08	0.23	
8	8.99	9.20	0.21	0.46	0.0631782	27	8.71	8.92	0.22	0.45	0.0478355
9	9.86	9.90	0.04	0.50	0.1042419	28	11.75	12.33	0.58	0.62	0.2299727
10	8.89	8.90	0.01	0.45	0.0750332	29	10.28	9.98	-0.30	0.50	0.102839
11	8.22	8.20	-0.02	0.41	0.0617077	30	11.38	10.94	-0.44	0.55	0.1277238
12	6.70	6.20	-0.50	0.31	0.0319779	31	10.60	10.81	0.21	0.54	0.1085441
13	8.00	8.20	0.20	0.41	0.0674732	32	11.71	12.11	0.40	0.61	0.2279975
14	7.61	8.10	0.49	0.41	0.0505801	33	15.65	15.04	-0.61	0.75	0.3535025
15	7.01	6.90	-0.11	0.35	0.0434644	34	2.51	6.37	3.86	0.32	
16	4.41	5.15	0.74	0.26	0.0121581	35	13.00	13.01	0.02	0.65	0.2280833
17	8.37	8.67	0.30	0.43	0.0698395	36	13.09	13.11	0.02	0.66	0.0155259
18	8.97	9.34	0.37	0.47	0.0627157	37	9.12	15.80	6.68	0.79	
19	10.00	10.17	0.17	0.51	0.0805457						

Table 1 Comparison of LiDAR forest height measurement and results of outwork

At the same time, by using the tree height measured by LIDAR as coordinate axis X, and the actual value as coordinate axis Y, we fitted the relationship of the two values with linear relation, quadratic polynomial and cubic polynomial method. As the result, the three methods had no significant difference from each other on the correlation analysis R2, all of which exceeded 0.98. This showed that a significant correlation existed between the tree height measured by LIDAR and the actual value. Han also showed that there was positive correlation between real tree height and tree height measure by LiDAR.(HAN Guang shun,2005)

With the rising of degree, the value of R2 is also increasing while the rate decreasing and the effect of the higher power terms were becoming smaller. Thus it is better to select linear function as the fitting function between the LIDAR tree height and the actual height. This also showed that, the LIDAE tree height had a positive correlation with the actual tree height. It can be said that, it will be feasible to measure the tree height with LIDAR technology, which can meet the demand of the tree height's investigation in forestry.

2.2 Fitting model of tree height and volume by LIDAR

Tree high by Lidar serves as x-axis, real measurement of volume as y-axis, the correlation between the volume tree and height was established. With the regression analysis between this factor and sample trees' tree volume, we set up the regression model between the two. Counting the total number of the *Sabina Viginiana* and height of each tree, we calculated the total forest volume of the *Sabina Viginiana* in the examining area through regression model of tree volume and tree height. From Figure 3, the point No36 (13.05,0.0155259) is an anomaly, regression analysis was carried out after striking out the abnormal point. Then, we fit respectively with polynomial as linear, quadratic, three, four, five, six times.

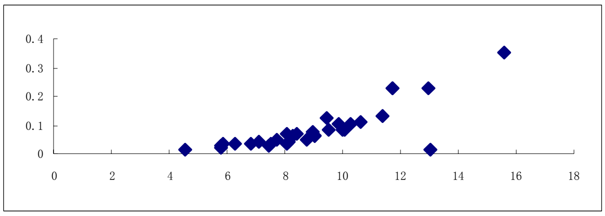

Figure 5 Points graph expressed a relation between trees volumes of surveying and trees heights fitted by LIDAR data

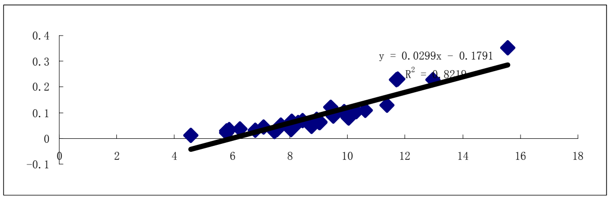

Figure 5 a linearity

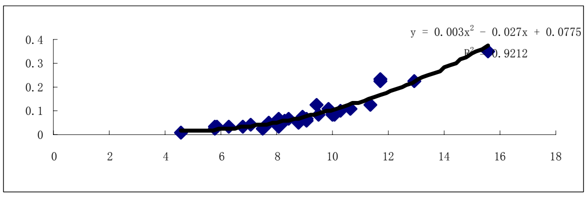

Figure 5 b Second-degree polynomial

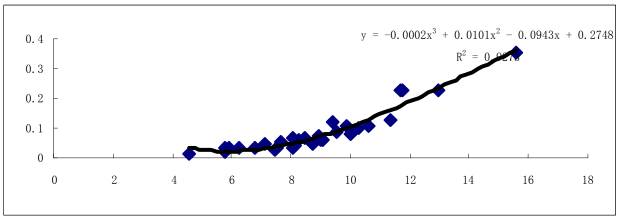

Figure 5 c cubic polynomial

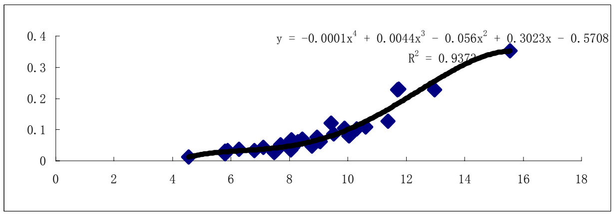

Figure 5 d Fourth-degree polynomial

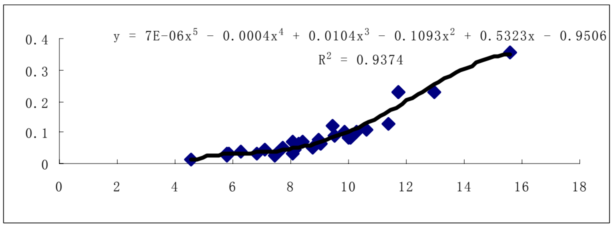

Figure 5 e Fifth-degree polynomial

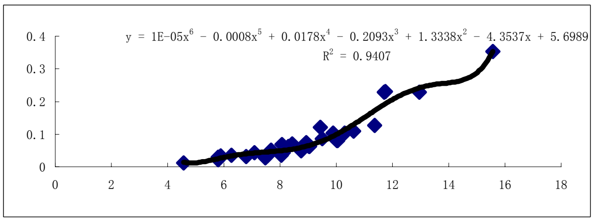

Figure 5 f sixth-degree polynomial

Figure 5 a ~ f regression between real volume and tree height by LiDAR after anomaly points were removed

According to the above curves, linear is not suitable as correlation coefficient R^2 of linear was less than others. From quadratic polynomial to six polynomial fitting results, the correlation coefficient changed slightly from the polynomial index increased by 4 times. From the analysis we can see that, it is better to select quartic polynomial to fit the relation between volume among the forests and the LIDAR fitting tree height.

The result was compared with forest volume measured by the standard field approach. And not big differences were found between the two. Its relative error is 4.25, satisfying the survey of Forest stand volume in the forest. This method offers a new method for the survey of Forest stand volume in the forest.

3. RESULT AND DISCUSSION

(1) The method of estimating forest stand volume with LIDAR technology will save amount of field work time and improve the work efficiency as well, however it will cost more than traditional measure methods.

(2) According to traditional forestry survey, the general requirements is millimeter for diameter at breast height, centimeter for height measured, and relative error is less than 5

per cent. From table 1, the average relative error is 0.913% which meets the requirement of forestry survey measuring.

(3) The above results showed that there is error and exceed error by use of LiDAR for height measurement, by analysis, there are mainly two main reasons as follow:

a) The relative density of point cloud was not enough.
For the top of tree, laser of LiDAR is often unable to reach the position [10]. It result that point cloud of trees was not inconsistent with the actual trees peak. Moreover, measurement objective is pines and cypresses, which may introduce error and exceed error;

b) The distribution of trees is relatively dense.
With high density of tree, "confusion" is more around the target, which would increase wrong judgments of tree tops or base tree. Therefore, it may introduce error and exceed error. This error often appear in the small distance between trees, the conclusions from the distribution of the surveyed area of trees have been verified.

Therefore, if used LiDAR measuring tree height of the tree entirely replace the high measurement, the error need to be further discussed.)

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