STUDY ON APPLICATION OF THREE-DIMENSIONAL LASER SCANNING IMAGING SYSTEM IN TREE MEASURING

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ABSTRACT:

In this paper, 3-D laser scanning imaging system was introduced to forestry measurement for data collection. Then the paper discussed the method for stand volume measure and crown measure by the new equipment. There are three methods to measure the stand volumes: using cylindricals and truncated cones to model the tree stem, collecting the point clouds of the tree stem to produce the surface of the stem to calculate volumes, the method of subsection integration to estimate the tree volume. Different methods fit to different trees with different shapes. In the measurement of stand crown volume, there are two methods to get the 3D models of the crown. The first is based on the point cloud data; the other method is to take the whole crown of the single tree as the components of the single small truncated cones. The method of using 3-D laser scanning imaging system could replace the traditional one in forestry was first to discuss. In experiment, 15 trees was selected to prove that 3-D laser scanning imaging system can be used in diameter breast height and tree height measurement. In stand volume estimation, the scanning system compared traditional sectional measurement method also showed high precision.

1. INTRODUCTION

The measurement science of forest is one of the basic subjects in the field of forestry, which studies on the forest itself and its products: timber, including the measurement, estimation and calculation(FENG Zhong ke, 2005; FAN Hai ying, 2004). In order to obtain the accurate measurement materials of the forest, the advanced measurement technology should be used because of the huge volumes and various shapes of the trees as well as the overlaps between the trees, which cause the difficulty to the work (ZHENG De hua, 2005; MA Li guang, 2005). The traditional method, wasting the resources and damaging the environment, is complicated, heavy-work loaded and needs cutting many trees. In a sense, it is not a preferred method.

So, in this paper, a new research has been done, which used the model to realize the automation and explored the feasibility of using the data from standing trees got by scanning replacing the data got from fallen trunks. The data got by the traditional measuring tools are single and of low efficiency, which give certain restriction to the model construction based on the data and other analysis (FAN Hai ying, 2004). On the contrary, 3-D laser scanning imaging system can show the models of standing trees (MAO Fang-ru, 2005). Therefore, more comprehensive measurement values can be provided to make as the reliable data basis for the study of trunks, shapes of crowns, volumes and biomass. What’s more, the new method can set a foundation for the dynamic monitoring of forest resources.

The purpose of the research was to have a exploratory study on the data collection method of using 3-D laser scanning imaging system to enrich the traditional measurement method, as well as the theory of forest measurement.

2. METHODS OF STANDING TREES VOLUME MEASUREMENT AND STAND CROWN MEASUREMENT

2.1 Measurement of standing trees’ scanning volume

The traditional sectional measurement of fallen trunks is like this: cutting down the standing trees and measuring the exact volume by method of subsection integration to estimate the tree volume. As for the scanning data, with the help of the coordinate matching function provided by the corresponding software of the 3-D laser (Cyclone) scanning imaging system, a whole point cloud model of a standard tree was got by the patching of the point cloud data. After the processing of data merging, rejecting the gross errors, automated segment extraction and TIN model structure, the details of sample trees will be modelled and finally get the 3-D models of the whole trees. The models can be rotated, translated, zoomed and angle-changed to measure the direct measuring factors like diameters (including the segment diameters), height and crown of the standing trees directly and conveniently. Then, trunk volume was got (ZHENG De-hua. 2005).

There are three methods of volume measurement using 3-D laser scanning imaging system. They are as follows:

2.1.1 Using cylindrical and truncated cones to model the tree stem

The calculation function of Cyclone software is used to calculate the exterior area and volume of the trunks (See below in Fig. 5). This method is suitable for the tree species with the shape of cylindrical, like pine trees and large birches. The advantages of this method is with great manoeuvrability and can compensate for point cloud data loss caused by equipment operation environment. As long as the value of point cloud

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data is small enough, each segment can be considered as the approximate cylindrical or truncated cones. However, Its disadvantage is that there are some difficulties in the data collection of trees' changing point and inevitably lose some volume data.

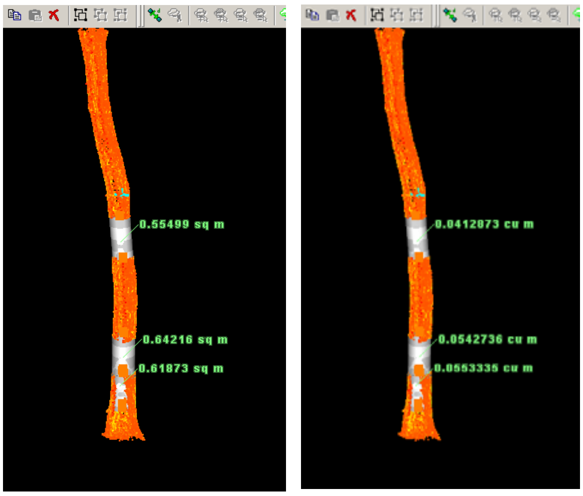

Fig. 1 Calculate exterior area and volume of trunk by trunk simulation based on column and frustum of a cone

2.1.2 Collecting the point clouds of the tree stem to produce the surface of the stem to calculate volumes

This method is suitable for the trees with straight trunk and less turning or with small angle, which is easily for choosing the projection plane (See below in Fig. 6 and Fig. 7)

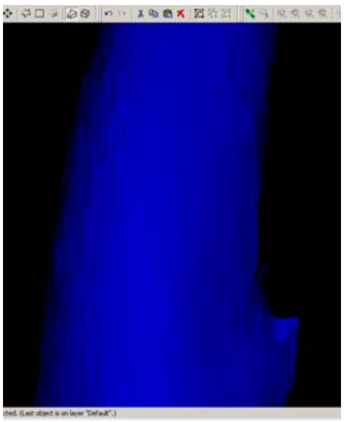

Fig. 2 Trunk simulation by data of point clouds

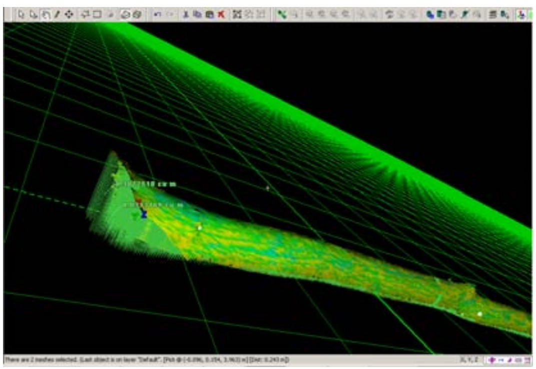

Fig.3 Measure the volume by Mesh of trunk

2.1.3 Traditional method of subsection integration to estimate the tree volume

This method, which is the traditional method in forestry, is to divide the trunk into several segments according to the forestry regulation. Through the manipulation of rotation, translation, zooming and angle changing, the segment diameters and height can be measured. Then, the tree volume can be calculated through the equation (See below in Fig.8)

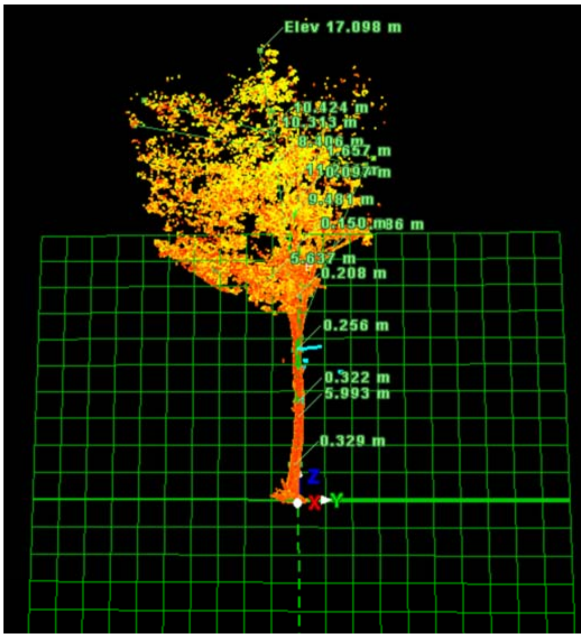

Fig.4 Measure the volume by mid-area

2.2 Stand crown measurement

In the measurement of stand crown volume, there are much differences with the tree stem measurement. As the crown is not a stationary solid form like the stem, there are many vacuity in the crown. The laser beam may penetrate the crown and form the reflection in it. So, the point cloud data we get can not totally reflect the spatial features of the outer crown. There are two methods to get the 3D models of the crown.

The first is to do some pre-process to the data acquired. We use Cyclone software to rotate and zoom the point cloud data, and then, manual interpretation is used to interprete the points that are not on the surface of crown and remove them. Next, we use the surplus data to set up a spatial Irregular Triangular Network (TIN) net, and calculate the surface area and volume of the TIN model according to the space geometry, approximate to the surface area and volume of the crown.

The other method is to take the whole crown of the single tree as the components of the single small truncated cones. Then, we measure part of the point data of the crown to calculate the surface area and volume of each small truncated cone. Next, all the results are added up and the surface area and volume of whole crown in the space are calculated. (See below in Fig5)

Stand crown calculation by height differences h_i of each cross section:

$$V = \frac{1}{3}\sum_{i=1}^{n}(S_{i-1} + S_i + \sqrt{S_{i-1}S_i}) \cdot h_i \quad (1)$$

(1) exterior area calculation fomula

$$S = \sum_{i=1}^{n}[(\sqrt{S_{i-1}} + \sqrt{S_i}) \cdot \sqrt{S_{i-1} + S_i - 2\sqrt{S_{i-1}S_i} + \pi \cdot h_i^2}\,] \quad (2)$$

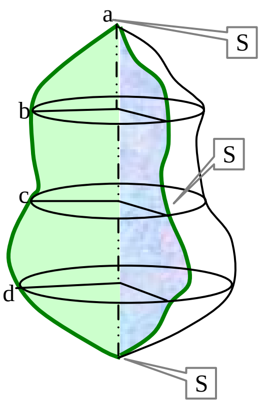

Fig.5 Measurement methods of common crown values

3. EXPERIMENT

3.1 Measurement of volume by three-dimensional laser scanning imaging system

The scanning data were got from these standard trees by measurement. Then, with the help of the coordinate matching function provided by the corresponding software of the 3-D laser scanning imaging system, a whole point cloud model of a standard tree was got by the patching of the point cloud data. After that, these data were preprocessed and some data with gross errors were eliminated. Moreover, the details of measuring targets were modeled through the functions of auto segmentation processing, extraction and TIN model construction. Then, the modeling of the whole measuring targets was finally accomplished (See below in Fig.4). Finally, the direct measurement factors like diameters (including segmented diameters), height and crown width were measured easily and directly with the help of rotation, translation, zoom and field viewing angle changing(HAN Guang-shun, 2005;).

In the experiment, on one hand, certain standard trees were shaded in all directions by the crown, so that the segmented diameters could not have been measured. On the other hand, gross errors existed in some measurement results of the diameters and height as the result of the external observation conditions changing. At last of this experiment, 15 of *Quercus aliena var. acuteserrata* trees were selected with different diameter class in Dangchuan forest farm of Xiao Longshan forest bureau in Gansu Province in China. We want to settle whether the method of using 3-D laser scanning imaging system could replace the traditional one in forestry.

We did the experiment to compare volume calculated by scanning system with the one by traditional sectional measurement method (DENG Xiang rui, 2005).

For volume estimation, traditional sectional measurement method are as follow:

(1) For tree height less than 10 meters, 1 meter serves as a section, the middle section serves as basal area, the volume can be calculated according to cylinder. For the tip at the top of the tree less than 1 meter, the volume is calculated according to taper.

(2) For tree height more than 10 meters, diameter breast height serves as the first middle basal area, 2.6 meters serves as the first section. For above 2.6 meters, each 2 meter is one section, the volume is calculated according to cylinder. For the tip at the top of the tree less than 2 meters, the volume is calculated according to taper.

The formula of trunk volume:

$$V = V_1 + V_2 + \ldots + V_n + V_{tip} = \frac{\pi}{4}\sum_{i=1}^{n} D_i^2 l_i + \frac{\pi}{12} D'^2 l' \quad (3)$$

In the formula, V is total volume of tree, $V_1, V_2, \ldots\ldots V_n$ are each section volume of tree, V_{tip} is tip volume of tree, D_i is diameter of each middle seciton, l_i is section length, D' is section diameter of tree tip, l' is tip length, n is section number. One point need to pay attention that when the tip section just meet the section length, the volume is calculated by cylinder.

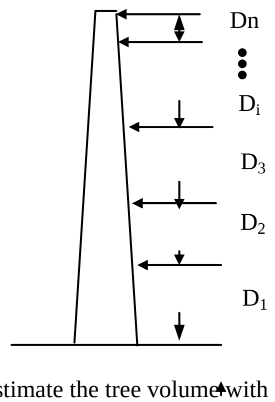

Figure 6 Estimate the tree volume with sectional measurement

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 3, the results of this comparison showed that the max relative error of diameter at breast height is No. 15 for -3.8%, the average relative error was 0.56 percent. The max relative error of tree height was No. 15 for -3.89%, the average relative error was -0.97%. This shows that three-dimensional laser scanning system can be used to access basic measurement of tree, this method sufficiently meet the accuracy of forest resources survey.

By scanning system, tree model can directly measure trees diameter (including sub-diameter), tree height and tree crown through rotation, pan, zoom and change view of field, then the trunk volume can be calculated. From results of Table 1, for the relative error of scan volume and real volume, the max error is No. 15, to -9.38%; besides three trees 1, 6 and 15, the relative errors are more than 5 per cent, the rest was less than 5 percent, the overall average relative error was -1.19%. Thus volume by generated model of three-dimensional laser scanning system is with high precision.

No.	Diameter breast height/ cm（D）	Tree height/ m（H）	Diameter breast height/ cm（D）	Tree height/ m（H）	Diameter breast height/ %	Tree height / %	Scanned volume/ m^3（V_0）	Real volume/ m^3（V_1）	Difference /%
1	4.20	4.93	4.1	5.10	2.44	-3.33	0.0049	0.0046	6.68
2	7.45	6.74	7.3	6.83	2.05	-1.32	0.0140	0.0135	3.57
3	12.40	9.72	12	9.47	3.33	2.64	0.0618	0.0646	-4.51
4	15.75	16.55	16.2	17.14	-2.78	-3.44	0.1740	0.1655	4.91
5	17.25	16.07	16.7	16.35	3.29	-1.71	0.1993	0.1907	4.31
6	18.80	13.71	18.3	14.22	2.73	-3.59	0.1822	0.1931	-5.97
7	20.85	14.12	20.4	13.79	2.21	2.39	0.2294	0.2406	-4.89
8	21.40	11.74	21.5	12.06	-0.47	-2.65	0.1975	0.2027	-2.63
9	22.80	20.02	23.2	20.43	-1.72	-2.01	0.4234	0.4125	2.57
10	24.05	17.26	23.8	16.84	1.05	2.49	0.3904	0.3784	3.07
11	24.85	16.43	24.2	16.03	2.69	2.50	0.3328	0.3476	-4.45
12	28.80	14.26	28.3	14.78	1.77	-3.52	0.3776	0.3940	-4.34
13	29.20	19.61	29.7	18.92	-1.68	3.65	0.6924	0.7064	-2.02
14	34.25	18.65	35.2	19.17	-2.70	-2.71	0.6919	0.7253	-4.83
15	38.00	19.76	39.5	20.56	-3.80	-3.89	0.9197	1.0060	-9.38

Table 1 Comparison scanning data and experimental data (ZHENG De-hua etc., 2005)

4. CONCLUTION AND DISCUSSION

(1) The tree stereo model can be acquired by using 3-D laser scanning imaging system. Therefore, the accurate measurement factors can be obtained, including some factors difficult to get by traditional method, like the exterior area and volume of stand crown.
(2) Through analysis, 3-D laser scanning imaging system is proved to be a new thoughts and method, which can replace the traditional manual measurement method. This new method is a supplement and improvement on the current method and its precision can meet the requirement of the precision forestry investigation.

(3) The data acquired by 3-D laser scanning imaging system is all digital product, which is easy to be preserved, processed and set up the data base. All these are easy to be put it into the digital forestry system.

(4) When using the 3-D laser scanning imaging system to acquire the measurement factors, this method will not do any damage to trees themselves, which is easy to do the continual observation and do the research on the forest dynamic monitoring.

(5) Using the 3-D laser scanning imaging system to measure the volume of standing trees provides a new thoughts and method for the measurement of factors and volume in the open forests, which is of great significance and meaning to the monitoring trees with efficiency and accuracy, but without damage.

(6) There are many elements affecting the scanning accuracy. For example, the scanning is badly affected by the shading of the crown and the surrounding trees, which will make part of data not very good. So, there exist certain problems of using 3-D laser scanning imaging system technique under the condition of the severe crown shading. However, this technique can better solve the measurement of standing trees volume in the open forest.

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