The New Method of Fruit Tree Characteristics Acquisition Using Electromagnetic Tracking Instrument

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Abstract. To achieve informatization for Orchards and fruit trees and to obtain real-time tree characteristic parameters in orchard, data acquisition system of fruit tree characteristics has established by using electromagnetic tracking instrument, Fastrack and data acquisition software. The process of acquiring tree's parameters and the method for acquiring tree characteristics using this system are discussed in detail. Finally, Outdoor measurement experiment was conducted on five 3-year-fruit trees in the experimental base. Five characteristics of fruit trees: tree height, the first main lateral branch height, angle between main branch and angle between main branch and a trunk, are acquired and compared with measurement results got from the traditional direct method. It shows that parameters of trees are basically the same: The difference of these two results is about 0.12cm ±0.06 cm. The relative error is less than 2mm and the mean difference in angle is no less than 1 degree. This means the proposed approach is feasible and has a high practical value.
Keywords: Fastrack; tree characteristics; fruit tree; measurement

1. Introduction

China is the world's first country of fruit production. In recent decades, fruit production is improved year by year and has become one of pillar industries in some agricultural provinces. During the actual production, an advanced system of orchard management techniques, production standards and fruit production in all aspects of high-tech are important guarantees to ensure sustainable growth in fruit production due to fruit characteristics of continuous production, technically demanding and long production cycle. It is essential for the establishment of China's fruit production technology system to obtain accurate data on the characteristics of fruit trees. The accurate and quantitative description to spatial form parameters of the fruit tree may not only provide reliable evidence for the establishment of fruit production technology system and production standards, but also provide technical support to the development of fruit morphology.

There is usually two ways to acquire the characteristics of fruit trees: Direct measurement, such as the traditional measuring by using tape and pole; indirect measurement, such as the coordinates of the tree's characteristic points can be obtained by using modern surveying, information technology and electronic technology. Direct measurement is not only inaccurate and heavy workload but also bad to fruit trees. Indirect measurement can effectively fill up the deficiency of direct measurement, so it has been increasingly applied in practical production. Wang Wanzhang et al (2006) built a tree crown diameter measurement test system in the tractor by using ultrasonic sensors, GPS receiver and electronic compass. Which can be tested by error analysis method, and the result is good. Tumbo et al detected the volume of fruit tree by using laser sensors and ultrasonic sensors, and compared the results of orange trees of indirect measurement and manual measurement. Comparison results show that the data obtained by indirect measurement have better accuracy than manual measurement. In addition, domestic and foreign scholars have also studied the effect of various external factors during indirect measurement on the measurement accuracy.

During the actual production, the local characteristic parameters of fruit trees are very important, such as the leaf length, leaf area, shoot length, branch diameter. The present research on fruit tree characteristics acquisition mainly focused on the acquisition to the overall characteristic parameters. There is only few studies use indirect measurement to acquire the local characteristics of fruit trees. For this reason, the article studies rapid acquisition of the characteristic parameters of fruit trees branches under the orchard environment by using electromagnetic tracking instrument FASTRACK and related software. Thus it provides a reliable basis for the establishment of fruit trees production technology system and pruning techniques. And then it provides technical support for the development of fruit morphology and pruning techniques.

2. Materials and methods

2.1. Measurement system

The system which our experiment used is composed of two parts: electromagnetic tracking instrument and the self-developed data acquisition software. The electromagnetic tracking instrument of our system is Fastrack which is developed by the Polhemus Corporation in the United States, as Figure 1 shown. Fastrack has always been considered the industry standard of electronic positioning during the last ten years. It provides the perfect solution for the position/orientation measurement and its Orientation tracker can accurately calculate the micro receiver's the orientation when it moves in space. The device eliminates the potential problems which are happened when it is carrying out dynamic 6 degrees of freedom to measure the position (Cartesian coordinates in the X, Y, Z coordinates) and orientation (azimuth, height and rotation). So it means that Fastrack is the most accurate electromagnetic tracking system. Data acquisition software system can display points' data collected in a graphical way and stored them into the database. Fastrack is connected with computer through the USB interface and is controlled by data acquisition software in computer. By this way, this system can collect Fruit characteristic point coordinate data and display them in graphical way, then store them in Access database.

Fig. 1. the Fastrack measuring equipment

2.2. Experimental Materials

In this passage, our experiment has been done in the test base of Fruit Research Institute of Chinese Academy of Agricultural Sciences, which locations in the east longitude 120 ° 44 ' and latitude 40 ° 36'. It attached to the city of Huludao. The Subjects of our experiment are five 3-year-apple trees which are chosen within Hua Xing and Hua Ping species (figure 2). Before the experiment, several tree parameters, such as height, branch length, section spacing and so on, should be measured by tape. These results which are gotten by tape can be used for comparison and analysis during the following experiment.

2.3. Experimental Methods

Fastrack that our experiment used is a measurement system based on the principle of electromagnetic wave and its precision of measurement is affected by External environment and the properties of subjects. For that reason, we must select the appropriate time and place based on the actual situation during the process of collecting data. For example, because the effective measurement range of Fastrack is limited by electromagnetic emission radius, the standard radius of Fastrack's transmitter is 1.2m. On the other hand, the height of the object in this experiment is about 2m. In order to ensure the integrity and accuracy of measurement data, the enhanced transmitting antenna of Fastrack is applied in our measurement. In the measurement process, we placed the transmitting antenna near to the target location of the tree and measured trees in the windless moment of morning or night so as to reduce the impact of external environmental factors and ensure the accuracy of experimental results.

Fig. 2. Fruit samples in the experiment

2.3.1. Equipment placement

Before measuring using Fastrack, equipment must be placed well. The process of placement includes three sections: GPS orientation, transmitting antenna fixed and checking the environmental impact. The purpose of equipment placement is to place the Fastrack transmitter in a stable position and ensure one of its axes parallel with the GPS antenna. At the same time, through the section of checking environmental impact, the device is less affected by external so as to ensure experiments carried out smoothly.

2.3.2. Measurement of spatial data

Fastrack that our experiment used is controlled by software, which means that there must be two people for measuring trees: one chooses feature points of trees by detector pen and the other uses data collecting software to record data of point and other information of trees. Before collecting information, the state of measuring equipment is checked by calibration module of the data collecting software and set ruler. On the other hand, coordinate origin of measurement that is represented by “O” should be set and all coordinate data of feature point recorded by the system are “O”-based. The O point is usually located in vertical intersection between trunk axis and horizon. The flow chart of measuring trees’ feature points is as figure 3 shown.

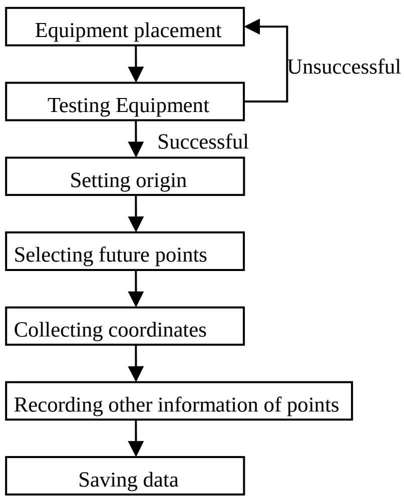

Fig. 3. Flow chart of measurement

During the measurement process, a set of rules is designed for choosing and measuring key points of trees so as to recorder the key data of fruit trees’ points. As the right side of figure 4 shown, six points which located in each knot of tree are chosen. On the other hand, between the neighboring knots, two points of tree are chosen for measuring which are as the right side of figure 4 shown. To measure as this rule, we can get $(n+1)\times 6+2\times n=8n+6$ data when measuring a branch with n knots. When measuring a tree, one operator chooses every selected point with detecting pen and coordinates of points are recorded by the data collation software. At the same time, the other information of selected points, such as point type and branch type, are also recorded for data analysis of the next step. As usual, a skilled operator can complete measurement of a fruit tree in 30 minutes, which can get data of 1000 points. All data collected are stored in ACCESS database.

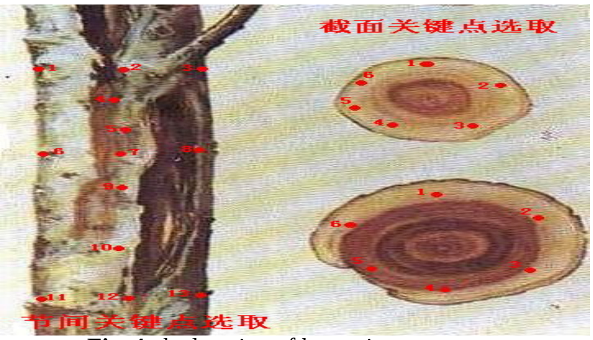

Fig. 4. the location of key point

The figure 5 is the interface of collecting software.

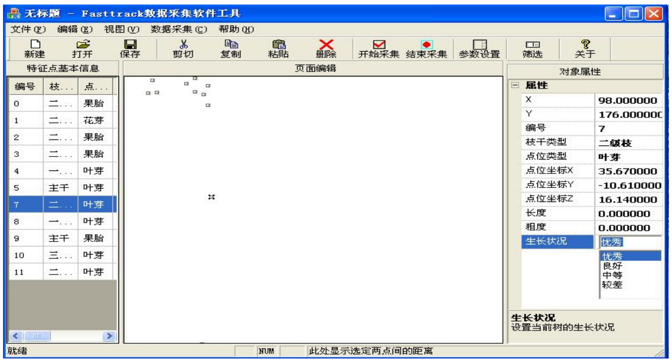

Fig. 5. the interface of collecting software

2.3.3. Calculation of characteristic parameters.

After having gotten feature points' three-dimensional coordinates of fruit trees with Fastrack, we can compute some tree parameters, such as height, stem length, shoot length, the angle between any stems, interlayer distance, crown width, crown diameter and so on , with these coordinates of collecting data in the software.

To any pairs of points on the branch: $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$, we can get distance between them with Formula (1)

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \quad (1)$$

By the formula (2), we can obtain any tree branch length:

$$\Delta d = \max(d_1, d_2, ...d_n) \quad (2)$$

where $d_1, d_2, ...d_n$ is the set of distance between any two feature points on the same branch.

The angle between any pair of stems can be computed by using the theory of the angle between two vectors, as Formula (3) shown:

$$\cos\theta = \frac{a_x b_x + a_y b_y + a_z b_z}{\sqrt{a_x^2 + a_y^2 + a_z^2} \times \sqrt{b_x^2 + b_y^2 + b_z^2}} \qquad (3)$$

As the same principle, the interlayer distance of a tree can be gotten by using the distance between any two vectors, as Formula (4) shown:

$$d = \left| proj_u \overline{AB} \right| \qquad (4)$$

where $proj_u$ represents the vector projection of AB onto the axis.

$P = \{(x_i, y_i, z_i)\}$ is a set of feature point coordinates of a fruit tree, where $i = 0,1,2...n$.

$$\begin{cases} \Delta x = \max(x) - \min(x) \\ \Delta y = \max(y) - \min(y) \\ \Delta z = \max(z) - \min(z) \end{cases} \qquad (5)$$

According to Formula (5), tree height is given by Formula (6)

$$h = \Delta z \qquad (6)$$

Based on the same principle, crown width of a fruit tree can be given by Formula (7)

$$f = \frac{\Delta x + \Delta y}{\Delta h} \qquad (7)$$

where Δh represents the crown height of a fruit tree.

3. Results and Analysis

We have measured the height and the first major lateral branch height of NO.1st to 5 trees with a tap in detection height of Fastrack. The angle between main branches and the radian between the main branch and trunk can be gotten by micrometer. Theoretically, when measured, the lower the tree height, the more accurate the detection as the tree having more close to the transmitting antenna of Fastrack. Measurement results of these five fruit trees with two kinds of measurement methods which are mentioned above, are shown in table 1 and table 2.

From the data of table 1, for NO 1st to 5th trees measured with a tape and micrometer, the average height is 132.97cm, the average height of first major lateral branch is 31.00cm, the average angle between main branches is 37.2 degree and the average Radian between the main branch and trunk is 1119.4 degree. Meanwhile, from the data of table 2, for NO 1st to 5th trees measured with Fastrack, the average values mentioned above are 133.04cm, 30.89cm, 36.8 degree and 119.8 degree.

Comparing mean parameters of fruit tree gotten by these two measure methods, we can find that the relative error of the height is the smallest while the angle between main branches' relative error is largest. Values of these errors are 0.05% and 3%. It means that the result gotten by indirect measurement with Fastrack is very near to that of direct measurement with tape. The difference of these two results is about 0.12cm ±0.06 cm. The relative error is less than 2mm and the mean difference in angle is no less than 1 degree. So results from indirect measurement with Fastrack have a very high precision, which can meet the needs of the measurement parameters of fruit trees.

Specific research and comparison dada in table 1 and table 2, we can find that the result of NO 3rd tree has the largest difference among two measurement methods. Because the result gotten by direct measurement is the mean value from the results of three professional operators, the error of direct measurement can be ignored. Further investigation can be found that the site of No 3rd tree is near to a pumped well which framework contains fixture. The fixture can affect the measuring tools of Fastrack that causes higher error. Meanwhile other trees relatively far away this pumped well which can get less influence by electromagnetic interference when measured and results of them have less error. Therefore, it is important for the accuracy of Fastrack to choose the right condition and smooth away the possibility of electromagnetic interference.

Table 1. Measurement results of fruit trees using tape

Tree number	1	2	3	4	5
Height(cm)	132.98	131.55	134.34	133.20	132.76
Height of first major lateral branch (cm)	26.31	31.26	29.87	34.66	32.89
Angle between main branches(degree)	34	36	39	40	37
Radian between the main branch and trunk(degree)	118	116	123	121	119

Table 2. Measurement results of fruit trees using Fastrack

Tree number	1	2	3	4	5
Height(cm)	132.76	131.84	133.99	133.56	133.06
Height of first major lateral branch (cm)	26.01	31.54	29.53	35.01	32.34
Angle between main branches(degree)	33	36	38	41	36
Radian between the main branch and trunk(degree)	117	115	125	122	120

4 Conclusion and discussion

In this passage, we select five 3-year-fruit trees in the experimental base of XingCheng Fruit Research Institute as research objects. Five characteristics of fruit trees: tree height, the first main lateral branch height, angle between main branch and angle between main branch and a trunk, are acquired With Fastrack. After compared these results with measurement results gotten from direct method with the tape and micrometer, it shows that parameters of trees are basically the same and relative error rate is no less than 3%. This means the proposed approach of Fastrack is feasible if the right condition is chosen and the possibility of electromagnetic interference is eliminated. Consequences using Fastrack have the same accuracy as measurement results gotten from the traditional direct method. This method using Fastrack which is characterized as convenient, fast and no damage has a high practical value.

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