Research on Real-time Tree Barrier Measurement System Based on Three Dimensional Lidar

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Abstract. Removing dangerous tree barrier is an important condition to ensure the safe operation of transmission line. A tree barrier measurement technology based on Unmanned Aerial Vehicle (UAV) is proposed in this paper. The technology detects the tree barrier near the transmission line by carrying Three Dimensional (3D) Lidar and on-board computer, de-noises the data obtained during the scanning process, aggregates and classifies the tree barrier data model. Combined with tree barrier measurement algorithm, a real-time tree barrier measurement system and method are formed. Field experiments show that the system can effectively improve the accuracy and efficiency of traverse tree barrier measurement, which is conducive to the realization of information, intelligence and safety of transmission line inspection, and has practical application value for the safe operation of the line.

1. Introduction

The tree barrier of transmission line corridor refers to the hidden danger to the line caused by the tall trees growing near the transmission line, thus the power failure occurs. Especially in summer, trees grow faster and storms increase. In order to avoid the occurrence of line tripping events caused by tree growth and line safety distance not meeting the requirements, cleaning up dangerous tree barriers in time is an important index for the safe operation of overhead lines. The occurrence of power outages caused by broken branches or toppling of trees directly affects the safe, economical and reliable operation of power grids[1][2].

Cleaning up dangerous tree barriers in time requires regular inspection of transmission lines, which can effectively eliminate possible hidden dangers or accidents, but the labor intensity and efficiency of manual inspection lines are high, the operation on high voltage lines is dangerous, and the environment of the lines is complex, the equipment is difficult to enter the barren mountains, UAV operation has become a new means of electric power inspection[3][4][5][6] So how to measure the distance between the tree barrier and the line during the inspection is the key to judge whether the tree is a dangerous tree barrier. With the continuous progress of measuring instruments, wire laser ranging, ultrasonic ranging and tilt photography ranging are widely used in the inspection of overhead transmission lines in China, which not only improves the accuracy of tree barrier measurement, but also enhances the efficiency of line operation. However, these methods have some shortcomings: first, wire laser can accurately measure the target distance, emit a very fine cluster of lasers to the target at work, and the coverage is small, so it is difficult to know the comprehensive tree information during the inspection process, so it is not convenient for future operation and maintenance management[7][8]. The second is that ultrasonic ranging uses ultrasonic emitters to send out ultrasonic waves, measuring the distance according to the time difference when the receiver receives the
ultrasonic wave, but the distance of ultrasonic wave measurement is limited in practice, and because the ultrasonic time difference is used to measure the distance, the sound speed is disturbed by temperature and wind direction, and it may be absorbed by the sound absorption surface. The actual measurement operation is unstable[9]Third, tilt photography ranging through the camera from different angles to capture images for 3D modeling, in practice, the line distance is generally longer, shooting time is longer, nowadays, the amount of unmanned power is not enough to support long distance tilt photography, and the later modeling time is longer[10][11].

Aiming at the defects of the above measurement methods, this paper proposes a real-time measurement system and method of tree barrier distance based on 3D lidar, which combines UAV technology, wireless communication technology and GPS technology with 3D lidar, which not only overcomes the influence of bad environment such as mountain area, but also presents the whole tree barrier environment in a three-dimensional and comprehensive way. The relative error is centimeter level, the system captures the wire through lidar, controls the speed and direction of the aircraft, detects the tree barrier information in real time during automatic inspection, and when the tree barrier information is detected, To control the camera to take pictures and record information, and to provide intuitive, scientific and effective analysis and decision data for managers to carry out operation and maintenance of transmission lines in the future. It provides reliable technical guarantee for electric power inspection and transmission engineering construction, and has good popularization and application value.

2. 3D Lidar
A Velodyne 16 line 3D lidar is selected in this paper. The aircraft terminal airborne computer is connected with the driver board of the lidar through the network port line, and the tree barrier detection system subscribes to its relevant information through the Velodyne driver of the ROS system to obtain the unanalyzed raw data.

- **Brief introduction of Velodyne 16 line 3D lidar.** Velodyne 16 line 3D lidar is the smallest 3D lidar produced by Velodyne company, which retains the function of adjustable motor speed. Real-time upload measurements of the surrounding distance and reflectivity. The Velodyne 16 line 3D lidar is easy to install and weighs only 830 g, which is very suitable for small UAV and small mobile robot. Velodyne 16 line specific parameters are shown in Table 1.

| Number of laser lines | Line 16 |
|-----------------------|--------|
| Scope of measurement  | 100 m  |
| Measuring accuracy    | ± 3 cm |
| Vertical measurement angle range | 30°(+15°—15°) |
| Vertical angular resolution | 2° |
| Horizontal direction measurement angle range | 360° |
| Horizontal angular resolution | 0.1°—0.4° |
| Measuring frequency   | Hz 5—20 |
| Laser Safety Level    | Level 1 (human eye safety) |
| Laser wavelength      | 905 nm |
| Sensor power          | 8 W   |
| Working voltage       | 9—32 V |
| Working temperature   | -10°C—+60°C |
| Output                | Up to 300,000 points per second |
| Network               | 100M Fast Ethernet connection |

- **Velodyne 16 line 3D lidar raw data preprocessing.** The Velodyne 16 line 3D lidar produces 300000 laser points per second. During the inspection process, the radar produces a huge
amount of data, which leads to the prolongation of the processing time of the airborne computer. Reduce noise and outliers by preprocessing the original data of point cloud. Finally, ROI (region Of interval) is left to reduce the amount of sampling data and the calculation of airborne computer. Through the through filter in the point cloud library of PCL (Point Cloud Library), the range of XYZ axis coordinates is filtered, the range of point cloud area is determined, and the remote distance point is eliminated. Then the obvious outliers and outliers are removed by statistical filter, and the interference of invalid data is eliminated. Finally, the sampling data is reduced and the computer processing speed is accelerated to achieve real-time feedback effect.

- Establishment of coordinate axis of 3D lidar. the point cloud corresponding vertical angle, azimuth angle and distance are obtained from the raw data R, and then its X,Y,Z coordinates are calculated for each laser point, as shown in figure 2. α The actual mounted radar structure is shown in figure 3.

![Figure 1. XYZ coordinate transformation of 3D lidar](image1)

![Figure 2. M210 Front and Side of 3D Lidar Mounting Structure](image2)

The airborne computer receives the original information of the 3D lidar and calculates the vertical distance of the tree from the wire in real time. Compared with the threshold, it is a tree barrier. Finally, the UA V can record the tree barrier area and record the tree barrier GPS data through the UA V RTK.

3. Tree Barrier Measurement Principle

3.1. System Composition
The tree barrier real-time measurement system based on 3D lidar consists of two parts: data analysis and control software system and hardware acquisition system. The hardware system is mainly responsible for collecting the spatial position information of the trees, recording the tree barrier record by the camera of the cloud head, recording the GPS information of the RTK, and running the software system in the on-board computer. The measurement process is shown in figure 3. The system includes the on-board computer, the 3D lidar data and the tree obstacle measurement algorithm on the UAV. The 3D lidar and the on-board computer carried by the UAV are used to detect and record and analyze the data from the starting point of the wire to achieve the purpose of data acquisition and processing. The GPS positioning accuracy of UAV is guaranteed by RTK differential method.
3.2. Measuring Principles

Figure 3. Flow chart of conductor tree barrier measurement

Figure 4. Profile of Tree Impairment Measurement Model
In figure 4, the side diagram of the ideal measurement model of 3D lidar is shown. It is defined that the horizontal azimuth of 3D lidar is 0 degree plane and the wire is in the same plane as the plane in space as the ideal ranging point. On the basis of the requirement that the safe horizontal distance between the aircraft and the conductor is 5 m, the minimum dangerous distance of the tree barrier is 7 m, the full coverage of the transmission line tree barrier detection area is realized. Ideal radar measurement angle range. $\beta \in [270, 305]$

Define a circle of radar laser scanning as a cycle T, as a calculation interval of the distance of the primary tree barrier, and the space distance between the aircraft and the detected tree, where the horizontal angle is the vertical angle. Defined as the distance set of tree obstacle detection points, $L$ the distance set of tree obstacle detection points from the small tower, and the clearance height of the tree detection point from the wire, $L(\alpha, \omega) = S H(\alpha, \omega)$

$$H(\alpha, \omega) = L(\alpha, \omega) \cdot \alpha \cdot \omega \cdot S \cdot H(\alpha, \omega)$$

$$H(\alpha, \omega) \in S \quad H(\alpha, \omega) < \beta \quad L_0 \notin L$$

$$\alpha_0 \in Q \quad L_0 = L(\alpha_0, \omega) \cdot \sin(\omega) + D \quad L_0$$

Among them, the tree barrier from the small tower distance, for the aircraft from the small tower distance. $D$

When there is overlap in the scanning area T the radar scanning interval, if there is a tree barrier in the overlapping area, the repeated recording tree barrier can be avoided $L \pm 2$ m.

4. Experimental Results and Analysis

4.1. Experimental Conditions

This paper selects a double circuit line with the same tower to carry on the field test, the ambient temperature is 29°C, the wind speed is 3 m/s. A multi-rotor UAV with 3D lidar was used for flight inspection. The 3D lidar data of #40-#41, #41-#42, #42-#43, #43-#44, #52-#53 were collected, and the tree barrier automatic measurement was carried out. On the other hand, the traditional means such as laser ranging telescope are used to measure the distance of tree obstacle, and the relative error is calculated by comparing with the measurement results of UAV system, so as to verify the accuracy of the method of measuring the distance of tree obstacle proposed in this paper.

4.2. Analysis of Experimental Results

![Figure 5. Photo of tree barrier taken during inspection](image1)

![Figure 6. Tree barrier report generated after inspection](image2)
The 3D lidar system is used to measure the distance of the selected line tree barrier in real time and take pictures as shown in figure 5, and the automatic report is generated as shown in figure 6. Then the laser ranging telescope is used to carry out the field measurement, and the results obtained by the two methods are fed into the field measurement Row comparison, analysis of relative errors, the results are shown in Table 2.

**Table 2. Comparative analysis of distance measurement of tree barrier**

| Measuring position   | 3D lidar measurement method (m) | Measuring methods for laser ranging telescopes (m) | Relative relative Error |
|----------------------|---------------------------------|--------------------------------------------------|------------------------|
| #40-#41 127.1 m     | 6.919                           | 6.905                                            | -1.33%                 |
| from small tower    |                                 |                                                  |                        |
| #41-#42 m 34.2       | 7.304                           | 7.337                                            | 0.20%                  |
| from small tower    |                                 |                                                  |                        |
| #42-#43 m 41.3       | 6.453                           | 6.447                                            | -0.45%                 |
| from small tower    |                                 |                                                  |                        |
| #42-#43 46.9 m       | 7.13                            | 7.140                                            | 0.09%                  |
| from small tower    |                                 |                                                  |                        |
| #42-#43 m 67.3       | 6.552                           | -0.14%                                           | 6.558                  |
| from small tower    |                                 |                                                  |                        |
| #43-#44 m 562.0      | 5.637                           | -0.09%                                           | 5.621                  |
| from small tower    |                                 |                                                  |                        |
| #43-#44 m 556.5      | 4.535                           | 0.28%                                            | 4.599                  |
| from small tower    |                                 |                                                  |                        |
| #43-#44 m 551.0 m    | 4.717                           | -1.42%                                           | 4.789                  |
| from small tower    |                                 |                                                  |                        |
| #43-#44 545.4 m      | 5.406                           | -1.52%                                           | 5.478                  |
| from small tower    |                                 |                                                  |                        |
| #43-#44 m 539.8      | 0.391                           | -1.33%                                           | 0.387                  |
| from small tower    |                                 |                                                  |                        |
| #43-#44 506.1 m      | 2.167                           | 1.07%                                            | 2.187                  |
| from small tower    |                                 |                                                  |                        |
| #52-#53 304.1 m      | 6.155                           | -0.90%                                           | 6.147                  |
| from small tower    |                                 |                                                  |                        |
| #52-#53 271.5 m      | 6.147                           | 0.13%                                            | 6.140                  |
| from small tower    |                                 |                                                  |                        |
| #52-#53 265.9 m      | 6.598                           | 0.11%                                            | 6.598                  |
| from small tower    |                                 |                                                  |                        |
According to the results recorded in Table 2, the maximum relative error between the measurement method based on UAV 3D lidar system and the traditional total station measurement method is less than ±1.5%, and the measurement results are reliable and effective. In addition, the method from field measurement to internal analysis and calculation, the total time consumption is reduced by 50%, which greatly improves the operational efficiency.

5. Conclusion
A real-time measurement method of tree barrier distance based on 3D lidar principle is proposed. The application of 3D lidar, wireless communication technology, GPS and UAV technology to tree barrier distance measurement of overhead transmission lines brings about the change of traditional methods and techniques, which not only overcomes the influence of field geographical environment, but also improves labor efficiency and has better precision of tree barrier distance measurement. The experimental results verify the effectiveness and feasibility of the proposed tree-range real-time measurement technology based on the principle of 3D lidar.

6. References
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