Automatic Detection of Transmission Line Dangerous Points Based on Point Cloud Tower Section Classification Mode

Long Xing1, *, Zhao Jian1, Wang Di1, Chen Yuran1, Liu Dandan1, and Wu Shaohua1

1Guizhou Electric Power Design&Research Institute, Power Construction Corporation of China, Guiyang 550000, China

* Corresponding author: 1721676081@qq.com

Abstract. In the actual laser power inspection data processing process, the classification error of point cloud is inevitable. Some classification errors often need to be located with the help of dangerous points which is detected by mistake. Therefore, in the process of laser power inspection point cloud data processing, the detection of Dangerous points often needs multiple calculations. However, the dangerous point detection is often based on the whole line, and involves the data calculation of hundreds of tower section at the same time. The data magnitude is large and the calculation speed is slow, which seriously affects the efficiency of point cloud category correction. Aiming at the above problems, this paper divides the point cloud into tower segments, transforms the calculation unit of dangerous point detection from a whole line to a single tower segment, and records the modification of the point category in the tower segment. In the process of correcting the classification error and repeatedly calculating the dangerous points, only the tower segment with the modified category is recalculated. The practical application shows that this method can effectively speed up the data processing efficiency of laser power inspection.

1. Introduction

Compared with the traditional manual line inspection, airborne LiDAR technology has been widely used in transmission line inspection because of its flexible operation and fast acquisition of high-precision point cloud. At present, the power grid has formed a periodic laser inspection mode, and a large number of scholars carry out the algorithm research of point cloud data in power application. Transmission line dangerous point detection has always been the core task of laser power inspection. At present, the commonly used detection methods are basically realized by kdtree or octree proximity search. However, the computation of proximity search is complex and time-consuming. Once the order of magnitude of point cloud is large, the computation time of dangerous point detection will be longer. With the development of radar equipment, the density of point cloud is further improved, which causes great computational burden for dangerous point detection.

Due to the inevitable errors in point cloud classification, the hidden danger points caused by classification errors can help classification personnel quickly locate the location of classification errors, and then correct the classification errors and re detect the dangerous points. Therefore, the hidden danger points are the important basis to verify and correct the classification of point cloud. In the process of data processing of laser power inspection point cloud, the hidden danger points often need to be repeatedly detected. However, the dangerous point detection is often based on the line, and the
repeated detection involves hundreds of repeated operations of line data. The data magnitude is large and the operation speed is slow, which seriously affects the efficiency of point cloud data processing.

In the process of correcting classification errors and repeatedly detecting dangerous points, only the category attributes of some tower sections are modified. At this time, it is unreasonable to recalculate all tower sections of the whole line. Therefore, this paper divides the point cloud according to tower sections, transforms the calculation unit of dangerous point detection from a single line to a single tower section, and records the modification of point categories in each tower section. In the process of correcting the classification error and repeatedly calculating the dangerous points, only part of the tower sections with the modified classification are recalculated to accelerate the speed of repeated detection of dangerous points.

2. Classification method of transmission line channel point cloud by tower section
According to the tower coordinates, the power line point cloud and vegetation point cloud are segmented into the point cloud set with the tower segment as the unit, the specific calculation process is as follows:

Traversing any point \( P \) in the transmission line channel point cloud, the coordinate of \( P \) is \((x_P, y_P, z_P)\). Starting from the \( i \)-th (\( i \) starts from 0) tower section, grading judgment is made, let the plane coordinates of small tower \( A \) is \((x_A, y_A)\) and the plane coordinates of large tower \( B \) is \((x_B, y_B)\). Firstly, calculate the maximum plane span \( D_{max} \) of this line according to the tower coordinates and the plane span \( D_{Ap} \) from point \( P \) to small tower \( A \). If \( D_{Ap} > D_{max} \), skip point \( P \) and continue to traverse the next point for grading judgment; else calculate the vertical distance \( d_p \) and horizontal distance \( l_p \) of point \( P \) in the \( i \)-th tower section.

\[
\begin{align*}
X_{AB} &= x_B - x_A, & Y_{AB} &= y_B - y_A \\
X_{AP} &= x_P - x_A, & Y_{AP} &= y_P - y_A \\
S_{ABP} &= (X_{AB} \times Y_{AP} - X_{AP} \times Y_{AB}) / 2 \\
d_p &= 2S_{ABP} / \sqrt{X_{AB}^2 + Y_{AB}^2} \\
l_p &= \sqrt{X_{AP}^2 + Y_{AP}^2 - d_p^2}
\end{align*}
\]

The vertical distance \( d_p \) is the vertical distance from point \( P \) to the line of tower \( AB \), and the line direction to the right is negative and the left is positive. The horizontal distance \( l_p \) is the projection distance from point \( P \) to tower \( a \) on the \( AB \) line.

\[
\begin{align*}
l_p &= \sqrt{X_{AB}^2 + Y_{AB}^2} \& \& (X_{AB}X_{AP} + Y_{AB}Y_{AP}) > 0 \& \& |d_p| < 50
\end{align*}
\]

When point \( P \) satisfies the constraint condition of formula (4), point \( P \) is added to the break point cloud of the \( i \)-th tower in the plane matrix with 100 meters bandwidth (commonly used in laser power inspection data) centered on \( AB \) line.

Let \( i = i+1 \), continue to judge the next level until the last tower section traverses the next point of the point cloud.

3. Duplicate detection algorithm of dangerous points in the process of point cloud category correction
Establish Boolean value array \( isChange \) to record the change of point cloud category of each tower section, which the length of the array is the number of transmission line tower segments, and the initial value of each element of the array is true. When the category of the point cloud of the \( i \)-th tower
segment is modified, set $\text{isChange}_i = \text{true}$, repeated dangerous point detection, the specific calculation process is as follows:

1. Let $i=0$, step by step;
2. If $\text{isChange}_i = \text{false}$, let $i=i+1$, repeat steps 2; else step by step 3;
3. Extracting power line points from point cloud $PC_i$ to build kdtree step by step 4;
4. Traversal kinds of points to be detected in point cloud $PC_i$, let the $j$-th point in point cloud $PC_i$ is $P_{i,j}$. Based on kdtree, determine the minimum distance $d_{i,j}$ between the point $P_{i,j}$ and the power line. If $d_{i,j}$ is less than the safety distance threshold of the point $P_{i,j}$ corresponding category, $P_{i,j}$ is Danger point. Let $j=j+1$, repeat the steps 4 until $P_{i,j}$ is the last point of the point cloud $PC_i$.
5. If $P_{i,j}$ is the last point of the point cloud $PC_i$, let $\text{isChange}_i = \text{false}, i = i+1$, repeat the steps 2.

4. Experimental analysis

In order to verify the practical application effect of this method, three transmission line point clouds with different lengths are selected for application analysis. The specific information of the three transmission lines is shown in Table 1.

First of all, the traditional mode is used to carry out category correction and dangerous point detection for the above three transmission line point clouds, and the relevant information in the processing process is counted, as shown in Table 2.

Secondly, the point clouds of the above three transmission lines are classified according to the tower segments, and the corresponding tower segment point cloud sets are obtained. The effect is shown in Fig. 1 ~ 3.

Last, the method of this paper is used to carry out category correction and dangerous point detection on the above three transmission line point clouds, and makes statistics on the relevant information in the process of processing, as shown in Table 3.

Through the comparison and analysis of Table 2 and table 3, it can be concluded that although the point cloud file separation processing is added in this method compared with the traditional detection method, the time of the file splitting operation is about 1/10 of the time spent in the detection of dangerous points, and only once is calculated in the category correction process, which can be ignored. However, the method can effectively accelerate the speed of non-first dangerous point detection. From table 3, the number of detection of dangerous points is significantly increased compared with table 1, that is, this method can use the dangerous points of false detection to assist the classification personnel to locate and classify errors quickly, and speed up the classification correction and detection processing speed of transmission line point cloud.

| Line Name | Voltage Level(kV) | Number of Towers | length(km) | Total Points(million) | Memory(GB) |
|-----------|-------------------|------------------|------------|------------------------|------------|
| 1st Line  | 220               | 20               | 5.6        | 61.5                   | 1.24       |
| 2nd Line  | 110               | 51               | 20.1       | 196.3                  | 3.98       |
| 3rd Line  | 500               | 181              | 93.6       | 589.7                  | 11.78      |
Through the comparative analysis of Table 2 and table 3, it can be concluded that compared with the traditional detection method, this method increases the point cloud classification processing, but the time-consuming of classification operation is about 1/10 of the time-consuming of dangerous
point detection, and it is only calculated once in the process of category correction, which can be ignored. However, this method can effectively accelerate the speed of non first dangerous point detection. It can be seen from table 3 that the number of dangerous point detection is significantly increased compared with table 1, that is, this method can use the wrong detected dangerous points to assist classification personnel to quickly locate classification errors, as shown in Figure 4, to speed up the processing speed of transmission line point cloud for category correction and dangerous point detection.

![classification accuracy](image1.png)

![classification inaccurate](image2.png)

**Fig. 4. Classification error location by danger point**

**Table 2. Statistical table of traditional mode category correction and dangerous point detection**

| Line Name | Single Dangerous Point Detection Time consuming | Dangerous Point Detection Frequency | Total Dangerous Point Detection Time consuming | whole process Time consuming |
|-----------|-----------------------------------------------|-----------------------------------|-----------------------------------------------|-----------------------------|
| 1th Line  | 2.1min                                        | 3                                 | 6.3min                                        | 12min                       |
| 2th Line  | 6.6min                                        | 5                                 | 33.0min                                       | 49min                       |
| 3th Line  | 20.4min                                       | 12                                | 244.8min                                      | 287min                      |
Table 3. Statistical table of method category correction and dangerous point detection in this paper

| Line Name | Segment Time consuming | Single Dangerous Point Detection Time consuming | Dangerous Point Detection Frequency | Total Dangerous Point Detection Time consuming | whole process Time consuming |
|-----------|------------------------|-----------------------------------------------|-----------------------------------|----------------------------------------------|-----------------------------|
| 1th Line  | 0.23min                | first 2.1min, and the subsequent calculation time is related to the number of tower repair sections | 10                                | 3.83min                                     | 5.74min                     |
| 2th Line  | 0.75min                | first 6.6min, and the subsequent calculation time is related to the number of tower repair sections | 23                                | 10.12min                                    | 14.56min                    |
| 3th Line  | 2.56min                | first 20.4min, and the subsequent calculation time is related to the number of tower repair sections | 87                                | 33.19min                                    | 45.64min                    |

5. Conclusion
In this paper, using the idea of grading, the point cloud is divided by tower section, and the calculation unit of dangerous point detection is converted from a single line to a single tower section. At the same time, the modification of the point category in the tower section is recorded. In the process of correcting the classification error and repeatedly calculating the dangerous points, only the tower section with the modified category is recalculated.

This method can effectively speed up the detection speed of non-first dangerous points. In the process of correcting the point cloud category, only the tower section of the modified category is recalculated, which can give full play to the role of false detected dangerous points to assist the classification personnel to quickly locate the classification errors, in order to improve the efficiency of transmission line point cloud classification correction and dangerous point detection.

Acknowledgments
This paper is one of the phased achievements of the project of Guizhou Provincial Department of Science and Technology "Beidou Satellite Power Industry Application key Technology Research and data Application industrialization" (2018) 3007.

This paper is one of the phased achievements of the project of China Electric Power Construction Co., Ltd. "Power Grid Application based on Beidou Satellite Navigation and data Analysis and Research of ubiquitous Power Internet of things" (DJ-ZDXM-2019-52).

This paper is one of the phased achievements of the project of Guizhou Provincial Department of Science and Technology "Research on Lean Operation and maintenance Technology of High Voltage Cable based on Intelligent Technology" ([2021] 288).

References
[1] Liu Y, Li Z, Hayward R, et al. Classification of Airborne LIDAR Intensity Data Using Statistical Analysis and Hough Transform with Application to Power Line Corridors[C] Digital Image Computing: Techniques and Applications. IEEE, 2010:462-467.

[2] Guan H, Yu Y, Li J, et al. Extraction of Power-transmission Lines From Vehicle-borne Lidar Data[J]. International Journal of Remote Sensing, 2016, 37(1): 229-247.
[3] QIN Xinyan, WU Gongping, PENG Xiangyang, et al. Power line reconstruction based on cable-patrolled LiDAR point clouds [J] Science of Surveying and Mapping, 2019(6)

[4] YIN Zenghui, SUN Xuan, NIE Zhengang. An automated extraction algorithm of power lines based on airborne laser scanning data [J] Geography and Geo-Information Science, 2012, 28(2):31-34.

[5] Guo Tao, Shen Ping, Shi Lei, Wang AWei, Li Xuesong, Liu Wenming, Wang Cheng. Study on power tower extraction and fast positioning from airborne LiDAR Data [J] Remote Sensing Technology and Application, 2018, v.33; No.161(03):156-161.

[6] SHEN Xiaojun, DU Yong, WANG Rende, et al. Inclination measurement of transmission line tower based on terrestrial 3D lidar [J] Journal of Electronic Measurement and Instrumentation, 2017(4).

[7] CHEN Liming, ZHANG Wei, YU Hong, et al. Application of UAV-based LiDAR system for power line surveys [J] Bulletin of Surveying and Mapping, 2017(S1):182-184.