Application of airborne lidar technology in transmission line survey

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Abstract: In the survey of transmission line, the traditional aerial survey method is difficult to get the surface elevation through the vegetation, corn field and other surface attachments, while the manual survey method has the disadvantages of low efficiency and high cost in mountainous and hilly areas. In this paper, the airborne lidar surveying and mapping technology is used, combined with a 110kV transmission line engineering survey example, generating high-precision surface DEM based on the point cloud classification results and extracting the single wood information based on the point cloud to accurately count the amount of tree felling. A panoramic simulation line corridor engineering geographic information system is established, which provides technical support for the route scheme optimization and plane section extraction, and is applied to the project. It is of practical significance to evaluate the effect.

1. Overview

In the survey and design of power lines, aerial digital photogrammetry is the main means to obtain DOM and DEM. However, there are some defects in the aerial image, such as blur, distortion, depth fracture and mutual occlusion, which lead to the incompleteness and fuzziness of the image information and reduce the adaptive ability of the existing automatic mapping algorithm [1]. Lidar technology has become a research hotspot in surveying and mapping, cartography, electric power, forestry and other application fields in recent years due to its high ranging accuracy and wide applicability of platform [2].

1.1. Technical advantages of lidar

Lidar technology has the advantages of high precision, high resolution, high automation and high efficiency. It integrates laser scanning, global positioning system and inertial navigation system technology, and is equipped with high-resolution digital camera, which can realize the synchronous measurement of the target and generate high-density laser point cloud data. Compared with the traditional measurement methods, lidar has the following advantages: (1) using POS and laser information can directly obtain the three-dimensional information of the target with real geographical coordinates; (2) high degree of automation: fully automatic data acquisition of the target area; (3) little weather impact: active remote sensing, data acquisition through active laser pulse emission; (4) high accuracy: ranging The highest accuracy can reach millimeter level; (5) strong penetration ability: it can penetrate vegetation to obtain high-precision terrain information; (6) fast data acquisition: it can transmit up to tens of millions of points per second, and quickly acquire large area data.
1.2. Overview of line engineering
The power transmission line project is located in the central plain area of Hebei Province, with the voltage level of 110kV. The site landform belongs to the plain landform in front of the alluvial diluvial mountain at the eastern foot of Taihang. The total length of the line is 10.5km, and the proportion of terrain is 20% in mountainous area, 25% in hilly area and 55% in plain area. The route is shown in Figure 1.

![Figure 1. Line trend diagram](image)

2. Operation process of Lidar aerial survey
The production links of lidar data measurement mainly include aerial photography design, aerial photography data acquisition, data preprocessing, laser data classification, digital elevation model (DEM) production and digital orthophoto (DOM) production. The detailed operation flow is shown in Figure 2.
3. Flight design

3.1. Ground base station

In the flight area, a GPS fixed reference station is set up, and the data collected by the ground GPS fixed base station is differentially measured with the data collected by the dual-frequency GPS receiver inside the POS system, and a continuous and more accurate sensor position is obtained through data processing. According to the requirements of differential GPS technology, the distance between the GPS base station and the onboard GPS cannot be greater than 30km. The details are shown in Table 1, according to this requirement, two base stations are designed to be evenly distributed in this aerial survey area.

| Site principle                      | Set up at the control point above GPS C level. The average distance between base stations is 30km. |
|------------------------------------|-------------------------------------------------------------------------------------------------|
| Base station equipment             | Dual frequency GPS equipment with endurance of more than 8 hours. Adopt Tianbao 5700 high performance dual frequency GPS equipment to improve the acquisition accuracy of ground equipment. |
| Observation requirements           | GPS receiver data sampling interval 0.5 s; The minimum number of satellites is 4; Satellite cut-off altitude angle 5 degrees; Measure the height of GPS antenna and fill in the observation manual and other relevant data. |
3.2. Route design
According to the basic technical and accuracy requirements of the airborne lidar measurement project, the project has designed 17 routes with a total flight length of about 80km. The route layout is shown in Figure 3.

![Route layout diagram](image)

**Figure 3. Route layout diagram**

4. Data processing

4.1. Data preprocessing
Since the accuracy of the IMU data is highly dependent on the accuracy of the GPS data, it is necessary to load the onboard data and the base station data, set the coordinates of the base station, and perform differential calculation on the GPS data through software to provide an accurate GPS data for fusion with the IMU data.

At the same time, the laser point cloud data formats acquired by different devices are different. The original 3D laser point cloud data acquired by the 3D laser scanning device is processed and converted into a common point cloud data format for subsequent data processing and product production.
4.2. Laser point cloud data processing and DEM production

The point cloud data is divided into several categories by a software automatic classification algorithm. The result product of this project is DEM. According to the DEM production process, we need to get accurate ground point cloud data. Therefore, in this project, we automatically divide the point cloud data into the following categories: ground, buildings, vegetation, low points, overlapping points, and so on. DEM processing flow shown in Figure 4.

Since the ground points separated by the automatic classification algorithm cannot be completely correct, manual intervention is required for manual classification, and the images acquired in real time are used as reference, and the incorrect classification is obtained by manual intervention to obtain the correct ground point. Figure 5 shows the ground point cloud data after correct classification:
After obtaining the correct ground point, the ground points are meshed and interpolated into a DEM with a spacing of 1 m. Figure 6 shows the DEM results of the project.

4.3. Data calibration
The calibration parameters of the inspection field mainly include 8 parameters for distance calibration and 3 angle parameters (roll, pitch, heading). The distance calibration parameters are shown in Table 2. The angle calibration parameters are shown in Table 3.

Table 2. Distance calibration results and accuracy

| parameter | A     | B     |
|-----------|-------|-------|
| 1         | -2.461| -2.461|
| 2         | -3.404| -3.479|
| 3         | -3.399| -3.486|
| 4         | -3.462| -3.478|

| accuracy /m | Dz=-0.011 |

Table 3. Angle calibration results and accuracy

| project     | Calibration result | accuracy /m |
|-------------|--------------------|--------------|
| Roll        | 0.005 706 371 3    | 0.034        |
| Pitch       | 0.006 619 043 5    | 0.044        |
| Heading     | -0.002 692 312 2   | 0.036        |

At the same time, in order to verify the accuracy of the above 11 calibration parameters, the project has set up 6 discrete inspection points in the calibration field, and field measured three-dimensional coordinates. The specific accuracy is shown in Table 4.
Table 4. Inspection results of inspection point accuracy

| Number | Eastern coordinates /m | North coordinates /m | Measured elevation /m | Point cloud elevation /m | dH/m |
|--------|------------------------|----------------------|-----------------------|-------------------------|------|
| xk1    | 579048.888             | 4295229.441          | 187.866               | 187.77                  | 0.096|
| xk2    | 580379.584             | 4294613.604          | 182.252               | 182.12                  | 0.132|
| xk3    | 581337.491             | 4294388.054          | 172.877               | 172.78                  | 0.097|
| xh4    | 582294.614             | 4294138.903          | 129.046               | 129.01                  | 0.036|
| xk5    | 585752.294             | 4294225.53           | 104.996               | 104.89                  | 0.106|
| xk6    | 586625.409             | 4292645.748          | 69.009                | 68.98                   | 0.029|

average value: 0.083 Maximum: 0.132 Medium error: 0.091

5. Engineering Applications

The DEM results and the simultaneous acquisition of DOM results were imported into the three-dimensional design platform of the transmission line. At the same time, the digital model of the ground and the ground objects was established based on the laser point cloud classification data, and the geographic information system of the line corridor panorama simulation project was built. In the system, according to the safety distance regulations in the Design Code for 110kV~750kV Overhead Transmission Lines, accurate spatial distance measurement of residential buildings, buildings, trees and other cross-overs in the transmission line corridor, real-time optimization of circuit design, generate a line plan view (Figure 7).

![Figure 7. 3D scene and flat section](image)

At the section of the line drilling high-voltage power line, the point catenary is used to extract the 220kV lower catenary line, and the optimal drilling point is selected according to the sag height, which avoids the need to measure the drilling line height repeatedly due to the drilling plan change. (Figure 8). At the point where the line spans into a piece of wood, the point cloud data is used to extract the height of the canopy, and the amount of tree felling in the line channel cleaning is accurately calculated to reduce the investment waste caused by the estimation inaccuracy.

Automatic extraction of vegetation layers by point cloud, combined with transmission line channel image, power line three-dimensional topology, and vegetation type data in transmission line channels, can effectively analyze the safety line of the power line and the minimum distance of the power line from the ground under the maximum arc. Analysis, distance analysis of the power line from the surrounding vegetation in the case of maximum sag or wind deviation. In the process of statistic of vegetation deforestation, the distribution range of forest area can be judged, and the height of vegetation can be accurately extracted.

In the process of transmission line design, there are strict requirements for vegetation deforestation. Based on the point cloud classification technology route, the sensitive classification of the design is
used to realize the automatic classification and single-tree segmentation of the vegetation area, providing data support for accurate design. (Figure 9).

![Figure 8. Drilling over 220kV power line point cloud data](image1)

![Figure 9. Single cloud segmentation extraction of point cloud data](image2)

6. Conclude
For the survey and design of transmission lines, in areas with more surface attachments such as houses and vegetation, how to obtain high-precision surface DEM by means of aerial survey has always been a technical difficulty. This paper summarizes the advantages of airborne lidar technology compared with the traditional aerial survey methods through an example of 110kV transmission line survey: (1) the laser point cloud can penetrate the vegetation and obtain the real elevation of the surface. (2) according to the point cloud classification data, the three-dimensional coordinate information of line crossing objects such as 10kV, communication line, house and so on can be extracted, and the safety distance can be measured in real time. (3) in North China and other areas with severe haze, lidar is less affected by weather, which greatly shortens the generation period of survey results.

Reference
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