

# Method Research and Accuracy Analysis of Oblique Photogrammetry in power line Inspection

C C Rao<sup>[1]</sup>, Z H Xu<sup>[2]</sup> and R C Liao<sup>[3]</sup>

<sup>1</sup>Guangdong Province, Guangzhou City, Li Wan District, Guangdong Electric Power Machine Inspection Center

<sup>2</sup>Guangdong Province, Guangzhou City, Li Wan District, Guangdong Electric Power Machine Inspection Center

<sup>3</sup>Guangdong Province, Guangzhou City, Li Wan District, Guangdong Electric Power Machine Inspection Center

**Abstract:** With the development of drones, drone power inspection has become the main method of power inspection. Because of its safety, efficiency, and economic characteristics, it has been favored by the power grid. This paper discusses the application background and technical characteristics of three-dimensional modeling based on tilt photography technology in power inspection, and proposes ways to improve the accuracy of 3D modeling and the accuracy of channel defects. then, we test on a certain line in Qingyuan and have achieved good results. The modeling effect and modeling accuracy provide a high-precision and reliable operation method for the drone power patrol and can be realized.

## 1. Introduction

With the continuous development of the national economy, the size of transmission lines is becoming larger and larger. A large number of transmission lines are built in dense forests and harsh environments such as mountainous areas. This poses a huge hidden danger for the safe operation of transmission lines. At the same time, it also brings considerable trouble to the inspection of transmission lines. In order to accurately and timely grasp the changes in the operating environment of the line, timely discover the growth conditions of the trees near the transmission line, etc., and determine whether this will affect the safe operation of the transmission line. However, the disadvantages of traditional manual inspection methods are very obvious. There is an urgent need for a three-dimensional corridor that can directly reflect the actual direction of transmission lines, the growth of forest trees and the detection of tree barriers, to provide comprehensive data on the clear, complete, and readable measurements of the transmission line corridors, and to meet the management needs of access road trees.. On the other hand, the collected data and corresponding computer software systems can also be used to carry out predictions and intelligent reminders of critical sensitive points such as surrounding buildings and tree barriers under different load conditions, and can provide assistance for actual line operation and maintenance.

---

[1] Master graduate student, Guangdong Power Grid Co., Ltd. Machine Inspection Center

[2] Ph.D., Senior Engineer, Guangdong Power Grid Co., Ltd. Machine Inspection Center

[3] Master graduate student, Guangdong Power Grid Co., Ltd. Machine Inspection Center



Tilting photogrammetry technology is a high technology developed in recent years in the field of international surveying and mapping of remote sensing. By picking up multiple sensors on the same flight platform and collecting images from different angles such as vertical and inclined, it is possible to more realistically reflect the reality of features. The situation overcomes the limitations of traditional photogrammetric techniques that can only be taken from vertical angles, and makes up for the lack of orthophotos<sup>[1]</sup>. Review of oblique photogrammetry techniques [EB/OL Chinese Science Paper Online, 2012, 05.]]. Using the method of batch extraction and pasting of textures from oblique images can greatly reduce the cost of 3D modeling, and it also has the characteristics of high-precision images, refined models, and model-realized data features<sup>[2]</sup>. Compared with the three-dimensional modeling using laser point cloud data, the three-dimensional modeling based on oblique photogrammetry technology has obvious advantages: First, the use of a wide range, low requirements for the drone equipped; second, the work head is light, with the same kind of drones, it can guarantee a longer life time; third, the price is cheap, but also can guarantee the accuracy of engineering applications. The three-dimensional modeling based on tilted photogrammetry technology can better solve the problems encountered in the transmission line inspection, so it has been favored by the power grid and has conducted in-depth research. This paper is based on the application of the three-dimensional reconstruction of transmission lines in Guangdong Province. The modeling accuracy of three-dimensional reconstruction from different production methods is analyzed, and the three-dimensional reconstruction method that is most suitable for the characteristics of transmission lines is demonstrated.

## 2. Experimental Process

### 2.1. Technical Process Formatting the title

Based on UAV tilted photogrammetry technology, using fixed-wing or multi-rotor UAVs as the flight platform, equipped with tilt photography camera to obtain high-resolution multi-view images in the survey area, using UAV image post-processing software to obtain fine three-dimensional model data. The overall technical process is shown in Figure 1<sup>[3]</sup>.

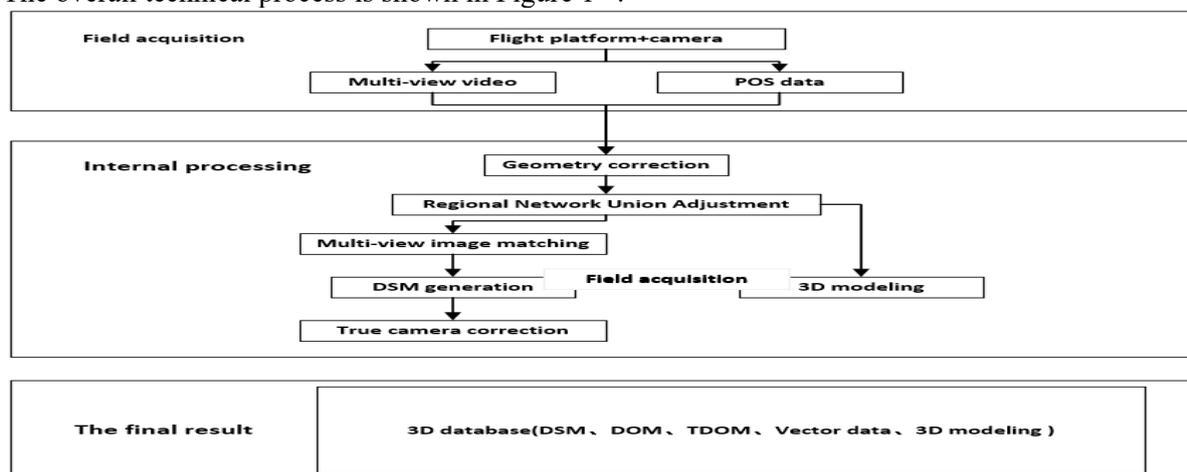


Figure1 Basic flow of tilt photography

### 2.2. Field data collection

The image data collected in this paper was obtained by using a drone equipped with a double-fighting camera to obtain oblique image data of a mountainous area and a certain plain in Qingyuan according to the heading of 70% to 80% and the overlap of 30% to 40%. At the same time, the same region of Lidar data was used as a benchmark.

Data used in this experiment:

- 1) Image data: Including 80 oblique images and 49 vertical images, a total of 139 images

2) POS data file: The file records the position and posture information of the drone flight trajectory and shooting exposure moments, including number, longitude, latitude, and elevation. The flight trajectory is shown in Figure 2:

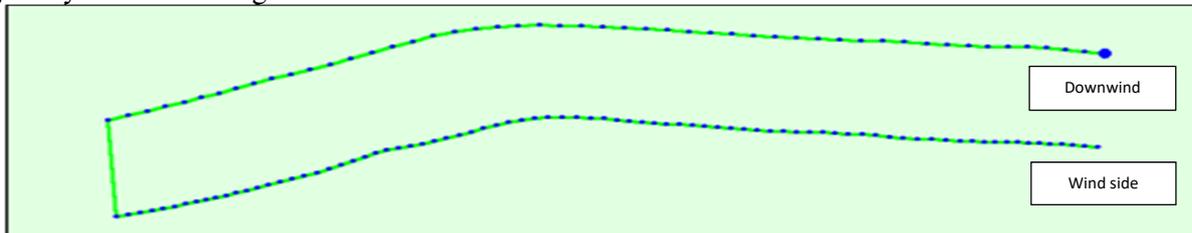


Figure2 Drone Flight Path

The green line in the figure is the flight path of the aircraft, and the blue point is the exposure point of the camera. It can be seen from the figure that the distances between the exposure points of the two navigation belts are different due to the influence of wind speed. The statistics of the separation distance and heading overlap between exposure points on the downwind side and the upwind side are shown in Table 1:

Table1 Comparative analysis of flight data

Airline	Exposure point interval (m)	Heading overlap
Downwind	31	78%
Wind side	20	86%

3) Differential GPS data file: Differential GPS (DGPS) is an additional (differential) correction signal outside the normal GPS to improve GPS accuracy

4) Laser point cloud data: The data acquired by the laser radar scanning, the collected laser point cloud data shown in Figure 3, the perspective of the line side view:

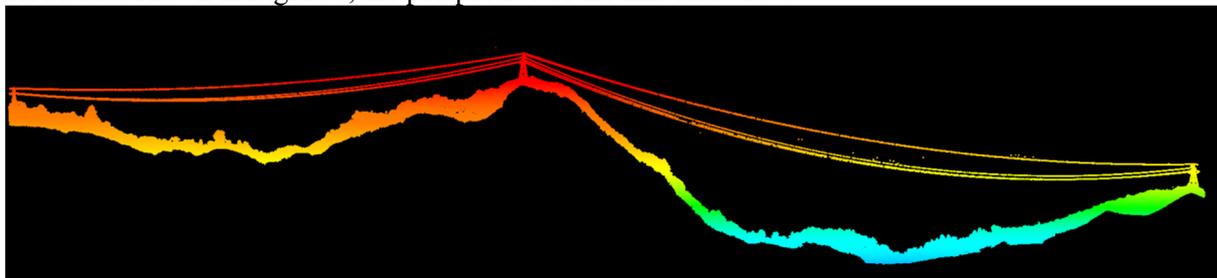


Figure3 Line Laser Point Cloud Data

### 2.3. Generate 3D scenes based on visible light images

On the basis of obtaining high-resolution multi-view image data of transmission lines and their surrounding environment, based on UAV image processing software, the three-dimensional encryption calculation is performed on the multi-view image data by using the regional network adjustment method to recover the image at the instant of shooting. Spatial location and posture; Using multi-view image intensive matching technology to obtain the coordinates of the same name of the image, and then obtain a high-density three-dimensional point cloud; According to the point cloud to build the feature TIN model, through the registration of each triangular face of the TIN model Slice and corresponding texture images, automatic texture mapping of the model, so as to obtain a three-dimensional model<sup>[4]</sup>.

Without ground control point data, the modelling effect is shown in Figure 4:

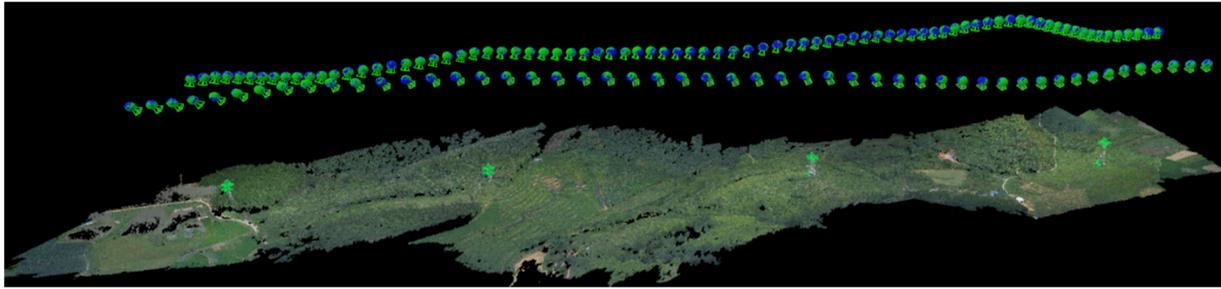


Figure4 3D reconstruction effect

### 3. Experimental accuracy analysis

#### 3.1. Analysis method

The purpose of this paper is to compare the effects of different terrains and different production methods (that is, production of single-frequency GPS and PPK data) on the effect of 3D reconstruction and analyze the accuracy of the results. The impact of modelling effects and modeling accuracy This article analyzes the two aspects of the number of connecting points and the aircraft flying height. The number of connecting points directly determines the effect of regional cyberspace, which directly affects the quality of surface point clouds generated by subsequent dense matching, and is a key indicator of three-dimensional reconstruction. Larger fluctuations in aircraft altitude will result in the shooting of instant photo attitudes and positions. The changes are important indicators that affect the accuracy of modeling. During the research of the project, it was found that different terrains and environments have a great influence on the effect of 3D modeling and on the accuracy of data. At the same time, multiple sets of tests were conducted in order to select the best data processing method and to reduce or eliminate noise interference. This article mainly analyzes the advantages and disadvantages of the existing operation methods from these two aspects, and analyzes the accuracy of the existing methods, and proposes corresponding solutions. Next, we will discuss two aspects of the effects of different terrains and different modes of operation on 3D modeling.

#### 3.2. Influence of Terrain on 3D Modeling

Utilizing the existing drone tilt photography high-definition image of a certain mountainous area line and a plain line in Qingyuan, a three-dimensional modeling was performed, and then the generated point cloud data was analyzed. The partial image after the point cloud data plus texture patch was shown in Figure 5 , Figure 6 shows:



Figure5 Qingyuan Plain

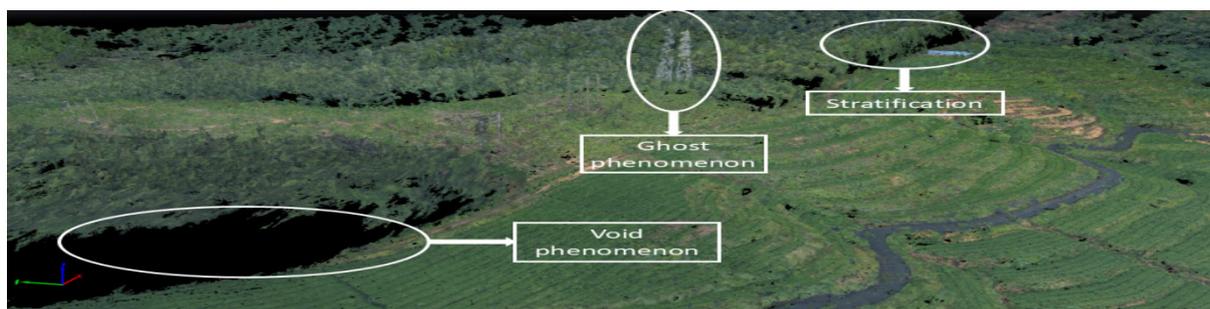


Figure6 A mountainous area in Qingyuan

Comparing the above two screenshots, intuitively the plain area is more reductive than the mountains. After the three-dimensional reconstruction of the mountainous areas, stratification, ghosting, and voiding occur, as shown in Figure 6 above. The vegetation and towers in the plain area were relatively clear and true, with no stratified ghosting.

For the differences that occur, this article analyzes the number of connecting points and the flight altitude:

1. Count the number of joints in ten consecutive images in mountainous and plain areas. The statistical results are shown in Figure 7.

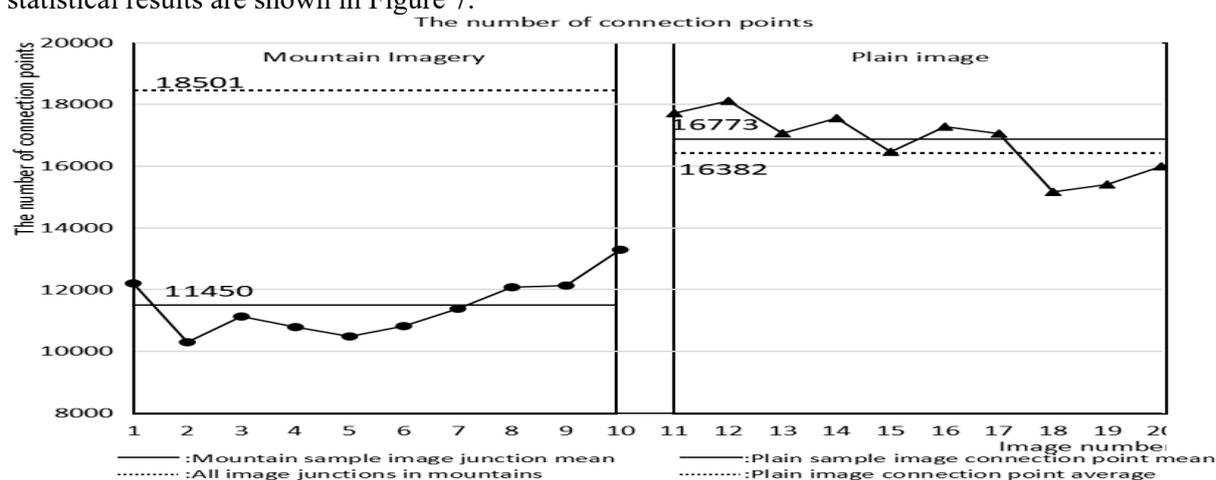


Figure7 Statistics of connection points

Calculate the standard deviation of the number of connection points and the mean difference between the number of connection points of the sample and all the images as shown in Table 2:

Table2 Difference Analysis of the Number of Connection Points

terrain	standard deviation	Difference between sample and overall mean
Mountains	897	7051
Plain	942	391

By comparing the number of connection points in the image:

The standard deviation of the number of image connection points in the mountain and plain samples is similar, indicating that the fluctuation of the number of local image connection points is not significant; however, the average number of connection points in the mountain and plain images is found: the number of connection points in the mountain sample image Far less than the plain area; the average number of connection points in the sample image of the mountainous area differs greatly from the overall average value, and the difference between the plain area and the whole is very small, indicating that the number of connection points in the mountainous area image fluctuates greatly and the plain area fluctuates. Very small, this is part of the reason that the local reducibility of the mountainous area is poor and the local reducibility of the plain is better.

2. The height of the ten consecutive image projection centers in the statistics screenshot is shown in Figure 8.

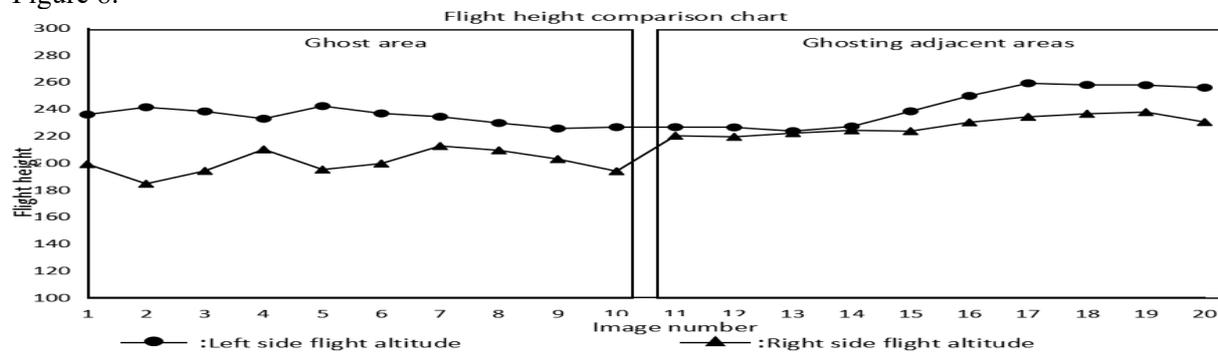


Figure8 Flight height statistics

The relevant indicators for calculating aircraft flight height are shown in Table 3:

Table3 Flight altitude indicators

terrain	Average altitude	Left-airway altitude variance	Right Band Height Variation	Average distance difference between two flights
Mountains	217	123	29	34.2
Plain	170	3.78	2.83	3.1

By comparing the height of the image projection center it is found:

From the height of the projection center of the image, the height of the aircraft on the two navigation belts in the mountainous area is obviously different, while the plain area is more consistent. The variance of the flight altitudes in the two navigation belts in the mountainous area is much greater than that in the plains, indicating that the flying height of the mountainous planes fluctuates greatly, while the plain area is relatively stable. The large fluctuation of the aircraft's flight height will cause the image distortion between the two navigation bands to increase, resulting in a decrease in the matching success rate of the connection points, and a large error in the attitude and position of the photos obtained from the air solution, and when the focal length is fixed. , Unstable flying height will cause large differences in the coverage area of the photo, and the degree of overlap will also change significantly, which increases the error of modeling data.

### 3.3. The effect of different operating methods on 3D modeling

#### 3.3.1. Briefly describe six operating methods.

The positioning accuracy provided by a single GPS system is better than 25 meters, and in order to obtain a higher positioning accuracy, we usually use differential GPS (DGPS) technology, with an accuracy of sub-meter level. Comparing and analyzing the effects of different GPS data on 3D modelling effects and adding manual connection points to obtain more accurate matching results, the following four groups of comparative experiments were done. The experimental data are shown in Figure 9 respectively:

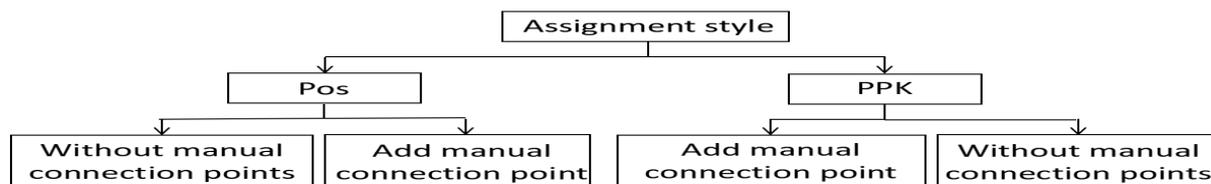


Figure9 Four sets of comparative experimental data

### 3.3.2. Test indicators

Measuring plane distance and elevation distance in four operation modes. In the results of the data obtained by the different methods of operation, three points of geographical coordinates are collected from each tower for two towers. Collect the coordinate information of the left and right hanging points and the tower feet, and obtain the plane information by measuring the distance between the two sides of the crossarm. Measure the distance between the two sides of the crossarm and the tower foot to obtain the elevation information, and finally obtain the elevation information. Compare the radar data to analyze the most accurate operation method.

### 3.3.3. Analysis of Modeling Accuracy

Analysis of the three-dimensional modeling data obtained from the four operating methods shows that the modelling results obtained from the unconnected data are generally not good, especially in dense forest areas where there are ghosting faults. After the three-dimensional reconstruction, the ghosting fault phenomenon is as follows: As shown in Figure 10, the ghosting effect disappears after adding the manual connection point, and the reconstruction effect is shown in Figure 11:

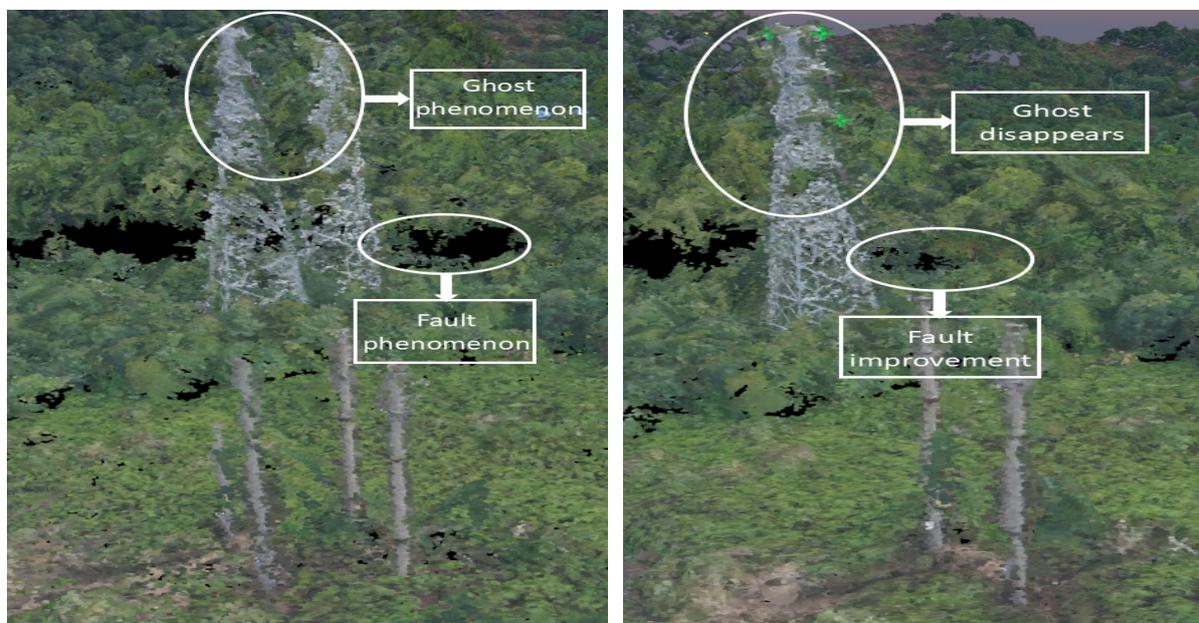


Figure10 Before joining the connection point      Figure11 After joining the connection point

From the comparison of the above two figures, it can be seen that the phenomenon of ghosting is obvious and the reduction effect is not good before adding the manual connection point, and adding the manual connection point, manually correcting the deviation of the matching point makes the ghost phenomenon disappear, and the three-dimensional modeling restore effect is better.

The phenomenon of ghosting is analyzed in this paper from the number of connection points of the image and the flight height of the aircraft obtained from the solution. The number of connection points and the height of the projection center in ten consecutive images in the screenshots of the ghost regions and ghosts are respectively calculated. The statistical results are shown in Figure 12 and Figure 13:

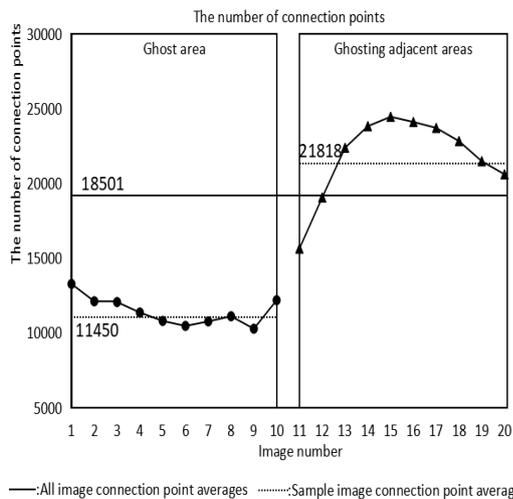


Figure12 Statistics of connection points

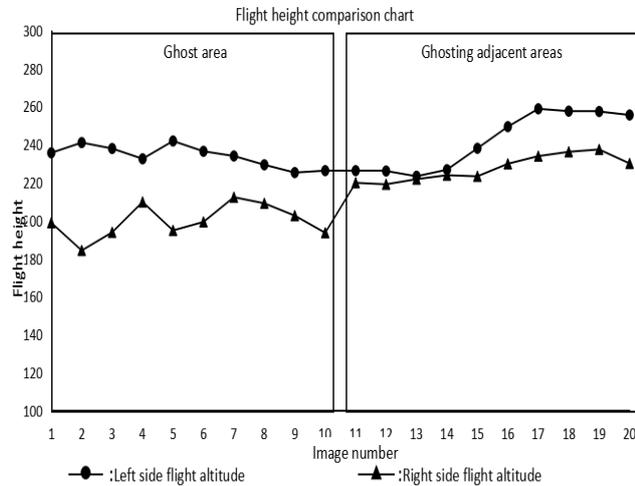


Figure13 Flight height statistics

Table 4 shows the relevant indicators for calculating the number of joints and flying heights of ghosts and their adjacent areas:

Table4 Mountain-related calculation index

terrain	Left standard height difference	Right navigation altitude standard deviation	Left and right navigation altitude mean difference	The standard deviation of the number of connection points
Ghost area	4.53	11.25	34.2	897
Ghosting adjacent areas	4.58	2.05	13.4	2619

By analyzing the data of two regions, you can get:

The ghost area is located in a dense forest area, while its adjacent area is located in a plain area with relatively few jungles. The average number of connection points automatically extracted in the ghost area is much less than that in its neighboring area, indicating that there are great differences in the number of connection points in different regions of the mountainous area. The flight heights of the aircraft on the two navigation belts from the height of the image projection center to the ghost area are quite different, while the flight heights on the two navigation belts in the adjacent areas are relatively small. The variance of the flying height in the right navigation zone of the ghosting zone is greater than that of the adjacent navigation zone, while the difference in the left navigation zone is not significant, indicating that the flying height of the aircraft in the right navigation zone of the ghosting region fluctuates greatly, while the flight altitude on the left navigation zone and its phase. The flying height in the neighboring area is relatively stable. The difference in flight altitude between the right and left flights and the large flying height of the aircraft on a single flight route resulted in fewer successful connections, and there was a large error in the attitude and position of the photos obtained from the airspace solution, and the ground range covered by the images. With the change, the number of connection points in different regions will fluctuate greatly, resulting in the quality of image matching in ghost regions being lower than that of adjacent regions. This is the cause of ghosting.

### 3.3.4. Accuracy Analysis

In order to analyze the accuracy of data obtained by different methods of operation, this paper uses the same area of Lidar data as a benchmark for comparative analysis. Elevation distance information and plane distance information are measured through four different methods of operation and lidar data.

The height and plane information of a certain route obtained from the PPK data and the single-frequency GPS data are shown in Figure 14:

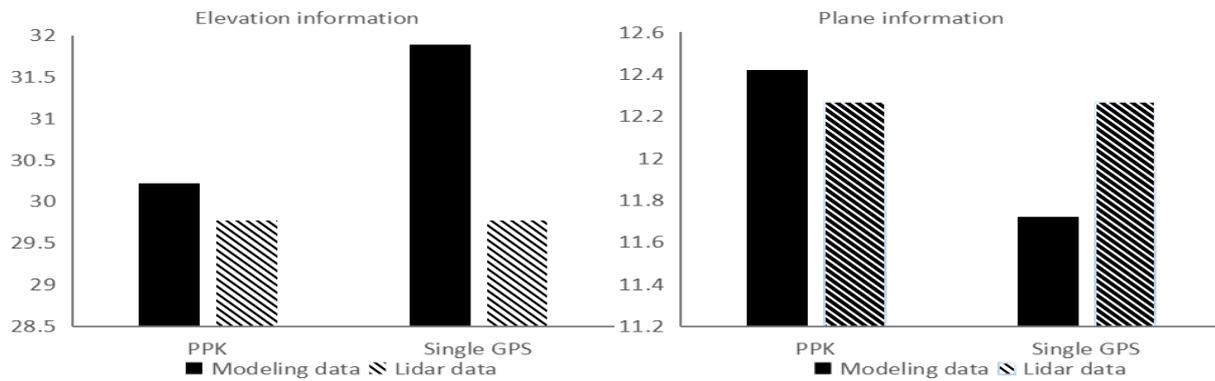


Figure14 Distance information

The error accuracy obtained by calculating the two methods is shown in Table 5.

Table5 Comparison of Error Accuracy Ranges

Assignment style	Height accuracy	Plane accuracy
PPK	1.5%	1.2%
Single GPS	7.1%	4.5%

According to the above data analysis, the plane and elevation accuracy obtained from the PPK data is much higher than that of the single-frequency GPS data based on the laser radar data. The plane and elevation information obtained from the PPK data are close to the laser radar data.

The elevation and plane information obtained by adding the PPK data and single-frequency GPS data to the manual connection point are shown in Figure 15:

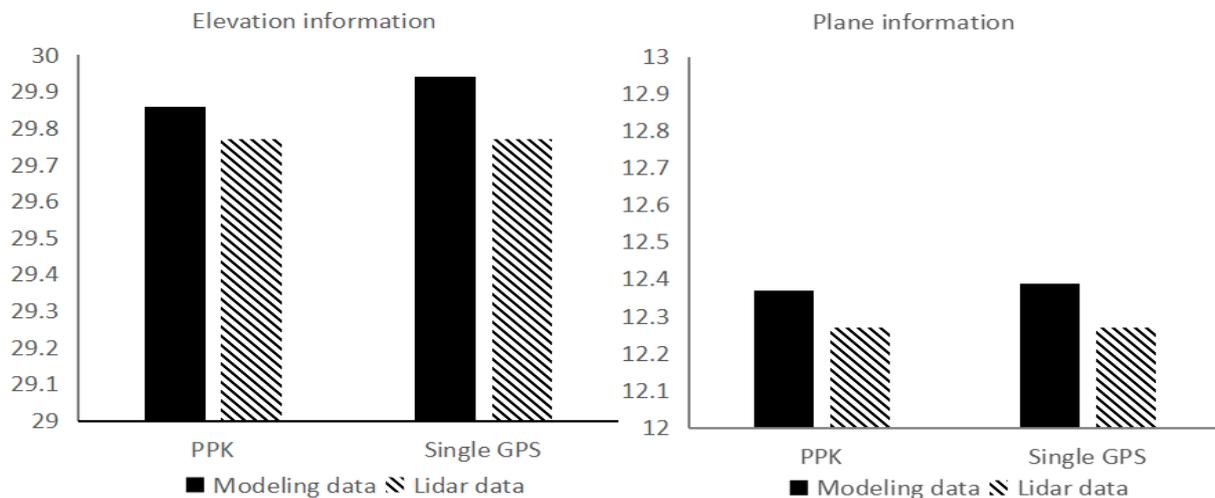


Figure15 Distance information

Calculate the error accuracy of the two methods after adding the manual connection point as shown in Table 6:

The error accuracy obtained by calculating the two methods is shown in Table 6.

Table 6 Comparison of Error Accuracy Ranges

Assignment style	Height accuracy	Plane accuracy
PPK	0.3%	0.8%
Single GPS	0.6%	1%

Through comparison and analysis of the above data, we can see that using Lidar data as the

reference value, adding the manual connection point, the modeling accuracy of the two has improved a lot, the error is within 1%, and the modeling accuracy of the PPK data is slightly better than the single frequency. The GPS data is closest to the reference value.

#### **4. 3D modeling analysis**

Lidar-based modeling method with high operating intensity and acquisition cost

High, follow-up data processing workload, only applicable to small area, fine

High-demand three-dimensional modeling of lines and substations in plain areas<sup>[5]</sup>.

Although the modeling method based on tilted photogrammetry is not precise enough, it has obtained in-depth research on the power grid and pilot application.

##### *4.1. Analysis of modeling effects*

From the analysis of the previous chapter, it can be seen that the modeling effect and modeling accuracy obtained from PPK data are better than single-frequency GPS data; the reduction effect in plain areas is better than that in mountainous areas, and the restoration effect in common areas in mountainous areas is better than that in dense jungle areas. . The data obtained from the PPK data after adding the manual connection point is closest to the lidar data, and the consistency of repeated experiments is good. Adding manual connection points to both production methods can significantly improve the reduction effect and improve the modeling accuracy.

##### *4.2. Problems*

On a large scale, existing technologies have high requirements on the quality of image data. Due to the complexity of outdoor environments, uncertain factors such as weather, light, and wind speed have a greater influence on the quality of collected images, leading to greater errors in later processing. . At the same time, due to the short life time of multi-rotor UAVs, the problems of large image data redundancy and excessive manual participation have led to low data processing efficiency.

In terms of specific details, the unstable flight altitude and the large difference in flight altitude between the left and right navigation zones will result in different coverage areas, resulting in a different number of connection points for automatic image extraction; a large fluctuation in the number of connection points will have a direct impact. To modeling effect and modeling accuracy.

Therefore, how to solve the problem of large aircraft flight height fluctuation due to the complex terrain in the mountains and the large flight altitude difference between the left and right navigation bands; how to improve the quality of collected data and how to improve 3D modeling by optimizing the distortion correction algorithm and the empty three-measurement algorithm The accuracy of the effect and data processing is a realistic problem that the current researcher needs to solve. It also needs to formulate the corresponding operation standard.

#### **5. Summary**

On the basis of the multiple comparison experiments, this article summarizes the following conclusions and existing problems:

1. Using PPK data and image data, adding manual connection points at the same time is the best mode of operation. The three-dimensional reconstruction has the best effect and the highest accuracy, and has little interference with noise.

2. The modeling error obtained from the original GPS data is as high as several meters, the generated point cloud density is low, and the modeling effect is not ideal. After the data processed after the difference, the modeling effect and modeling accuracy are better than the original GPS data.

3. Regardless of the production method, the improvement of modeling effect and modeling accuracy after adding the manual connection point is obvious. After adding the manual connection point to the model obtained from the PPK data, the error is only in the centimeter level. The level can meet the application requirements and can be applied to the engineering field. Therefore, in 3D

modeling, it is necessary to add manual connection points to correct deviations in image matching in power applications, thereby improving the modeling accuracy.

4. At the same time, the paper also analyzes the existing problems, and the modelling effect is not very good when dealing with complex environments. Follow-up will continue to optimize this by arranging ground control points and improving the quality of the collected images. It will be the most effective solution for 3D modeling of transmission lines.

### References

- [1] Zhu Qing, Xu Guanyu, Du Zhiqiang, et al. Review of oblique photogrammetry techniques [EB/OL]. China Science and Technology Papers Online, 2012, 05.
- [2] Sun Hongwei. Three-dimensional digital city modeling based on oblique photogrammetry technology[J]. Modern Surveying and Mapping, 2014, 37(1): 18~21.
- [3] Mai Xiaoming, Chen Chi, Peng Xiangyang, et al. 3D visualization and system design of transmission line corridors[J]. Electric Power, 2015, 48(2): 98~103.
- [4] Zhang Xiaowei. Research on fast three-dimensional modeling technology of transmission line tower system[D]. Beijing: North China Electric Power University, 2014.
- [5] Lin Biao, Wu Dun, Li Danong. High-precision power line survey based on airborne laser radar [J]. City Survey, 2011, (5).