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Research on 3D Model Reconstruction Based on UAV Oblique Photography

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Abstract. This paper uses the iFly D6 six-rotor electric UAV which is equipped with iCam Q5Plus camera to obtain the image of the test area by oblique photography. The real 3D model of the test area is obtained by indoor processing with the contextCapture software, and the accuracy of the model is analyzed by the measured field checkpoints. The RMS of the point in plane and elevation can meet the accuracy standard of I grade 3D model products.

Keywords: UAV, oblique photography, 3D model, RMS

1. Introduction

UAV oblique photography is an emerging technology that uses multi lens (mostly five lens) cameras mounted on the same drone flight platform to simultaneously collect vertical and oblique image data and corresponding POS data of ground objects from multiple directions and angles, and obtain texture information of ground objects [1][2]. UAV oblique photography has the characteristics of strong maneuverability, low cost, high efficiency, high accuracy, and strong safety, which is of great significance for modern surveying and mapping.

2. Acquisition of UAV Oblique Image Data

Before starting data collection, corresponding preparations need to be made to ensure the safety of personnel and instruments during the field collection period, and to ensure the smooth progress of flight operations.

2.1. Site Survey

Field survey refers to the organization of personnel to conduct on-site inspections of the operating area and surrounding environment before the official start of construction operations, familiarize themselves with the flight airspace conditions of the survey area, and understand the main geological and geomorphological characteristics within the survey area. There are no signal sources such as airports or high-voltage towers near the experimental area, and the weather conditions in the survey area are good, meeting the requirements of this test[3].

2.2. The Measurement of Image Control Points

In the process of UAV oblique photogrammetry, the control point data serves as the benchmark data, and its quantity, distribution, and accuracy indirectly affect the accuracy evaluation of the 3D model. To ensure the accuracy of the 3D data product in this experiment, according to relevant specifications, the control points in this experiment were mainly arranged using the regional network method, with 30 control points uniformly arranged. The plane coordinates and elevation were measured using a single base station network GPS-RTK positioning technology.

2.3. Field Aviation Flight

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This experiment uses the Zhonghaida iFly D6 six rotor electric UAV, the iFly D6 UAV has excellent electromagnetic resistance, strong adaptability, and super strong wind resistance. It can accurately hover, cruise at a constant speed, and has low voltage automatic return function, providing strong protection for the safety of the instrument. The oblique camera model paired with the drone is the Zhonghaida iCam Q5plus, which has 5 camera lenses and can simultaneously obtain image data from 5 directions. Based on the on-site survey and relevant specifications of aerial photogrammetry, design parameter information such as relative flying height, image overlap, and air route on the ground station software. Finally, the field flight was conducted on a calm and sunny day, and 7280 oblique images were obtained. After inspection, all the captured images covered the shooting area without relative or absolute flaws, and all the images were rich in layers, bright colors, saturated colors, and moderate contrast, which can be used for the production of 3D models in the later stage[3][4].

3. 3D Modeling of ContextCapture Software

ContextCapture software is developed by French company Acte 3D. Its working principle is to systematically analyze multi view images or point cloud data, automatically detect and identify the same ground object point in different multi view images or point cloud data, calculate the external orientation elements through intelligent algorithms, and generate a high-resolution 3D model of the ground object[5].

After importing image data using ContextCapture software, first perform aerial triangulation. After completing aerial triangulation calculation, check the 3D view. After checking and confirming the accuracy of the point cloud model, the specific positions of the control points are marked in the image. After the marking of points, the 3D view is checked to confirm that the point cloud model and the relative position relationship between the control points is correct. After that, the second aerial triangulation is submitted. Then create a new reconstruction project and submit a new production project for model production, generating a 3D model with rich textures and vivid details, as shown in Figure 1

Fig. 1: Real 3D model of experimental measurement area

4. Evaluation of Precision Accuracy

4.1. Evaluation of Accuracy in Aerial Triangulation

The accuracy of aerial triangulation directly determines the accuracy of the 3D model, and conducting accuracy analysis and monitoring during the aerial triangulation process is beneficial for improving the quality of the 3D model in the subsequent modeling process.

This article evaluates the accuracy of aerial triangulation calculation results using the mean square error formula. The formula is as follows:

$$m = \pm \sqrt{\frac{\sum(\Delta)^2}{n-1}}$$

After the completion of the aerial triangulation, export the aerial triangulation accuracy report. The aerial triangulation accuracy of each image control point is as follows:

The maximum error of 3D among 30 control points is 0.42mm, the minimum error is 0.05mm, and the median error is 0.17mm, the RMSE of 3D is 0.21mm; The maximum error in the plane is 0.38mm, the minimum error is 0.02mm, the median is 0.14mm, and the RMSE in plane is 0.17mm; The maximum error in elevation is 0.26mm, the minimum error is 0, the median is 0, and the RMSE in elevation is 0.12mm.

The accuracy of the aerial triangulation in this experiment meets the requirements of relevant standards and specifications.

4.2. Evaluation of 3D Model

After the completion of the 3D modeling of UAV oblique photogrammetry, use ContextCapture Viewer to open the model, select the measurement function, click on the three-dimensional model to view the real-time plane coordinates and elevation coordinates of the check points, and compare them with the actual values measured in the field to obtain the model error of each point (the difference between the measured values of the model and the actual values), and then evaluate the elevation and plane accuracy of the model.

Set up check points based on the principle of setting up control points of photos. Ensure that checkpoints are evenly distributed and have clear representativeness, such as road corners. A total of 26 planar check points were set up within the measurement range in this study. The model errors of each check point are shown in Table 1.

Table 1: The model error of 3D model checkpoints

Point number	ΔX	ΔY	ΔZ
1	-0.0047	0.0098	0.0209
2	0.0036	0.023	-0.0106
3	-0.0143	0.0048	-0.0046
4	-0.0048	-0.0092	-0.0051
5	0.0063	-0.0371	0.0509
6	-0.0038	0	-0.0131
7	-0.0103	0.0046	0.0039
8	0.0036	-0.0096	0.0129
…	…	…	…
26	0.0043	0.0127	0.0049

The formulas for calculating the RMSE in the model plane and elevation are shown as follows[6]:

$$\begin{cases} m_x = \pm \sqrt{\dfrac{\sum(\Delta x)^2}{n-1}} \\ m_y = \pm \sqrt{\dfrac{\sum(\Delta y)^2}{n-1}} \\ m = \pm \sqrt{(m_x)^2 + (m_y)^2} \\ m_z = \pm \sqrt{\dfrac{\sum(\Delta z)^z}{n-1}} \end{cases}$$

Among them, m_x, m_y, m_z respectively represent the RMSE of x, y, z. Δx, Δy, Δz represents the difference between the measured values of the model and the field measurements of x, y, z.; m represents the RMSE in plane; n represents the number of check points.

According to the above formula, the mean square error in the X and Y of the checkpoint can be calculated, as well as the mean square error in the plane and elevation, are shown in Table 2.

Table 2: Table of 3D model accuracy

Number of checkpoints	RMSE of north coordinate/m	RMSE of east coordinate/m	RMSE of plane coordinate/m	RMSE of elevation coordinate/m
26	0.012	0.017	0.021	0.027

According to the regulatory requirements, the specific evaluation criteria for the elevation accuracy of the 3D model are shown in Table 3, and the specific evaluation criteria for the plane accuracy are shown in Table 4.

Table 3: Accuracy standard of 3D model elevation

Level	Level I	Level II	Level III	Level IV	Level V
Mapping scale	1:500	1:1000	1:2000	1:5000	1:10000
RMSE in elevation of plane/m	0.37	0.37	0.75	1	1
RMSE in elevation of hilly area/m	0.75	1.05	1.05	2.5	2.5
RMSE in elevation of mountainous area/m	1.05	1.5	2.25	5	5
RMSE in elevation of high mountain areas/m	1.5	3	3	8	10

Table 4: Accuracy standard of 3D model plane

Level	Level I	Level II	Level III	Level IV	Level V
Mapping scale	1:500 (Field mapping)	1:500 (Non field mapping)	1:1000	1:2000	1:5000
plane accuracy/m	0.3	0.5	0.8	1.4	3.5

After comparing and analyzing the coordinates of 26 check points between field measurement and the 3D model measurement, it can be concluded that the plane mean square error and elevation mean square error of the 3D model generated in this experiment are 0.021m and 0.027m, respectively. Its accuracy meets the requirements of LevelIin 3D model products height mean square error and plane mean square error specified in *The Product Specification for 3D Geographic Information Model Data*.

5. Concluding Remarks

The 3D model constructed using UAV oblique photogrammetry technology is realistic, textured, and has high positional and attribute accuracy, greatly reducing the cost of 3D modeling and effectively improving the efficiency of model production. It can meet the requirements of existing standards in terms of completeness and logical consistency[4]. This article introduces the relevant technologies of UAV oblique photography 3D modeling, using CC software to complete 3D modeling and proving that the generated model meets the accuracy standards of Class I 3D model products. The generated model can be used to draw 1:500 topographic maps. In applications, it has also been found that the processing of oblique photogrammetric images requires high requirements for corresponding software and hardware:

(1) The software platform requirements are high. Although the oblique image processing software used in this experiment is highly automated, if the aerial photography parameters are not set properly during the aerial photography flight, or if the software options are not set properly during the image processing process, there may be loopholes or texture deformations in the 3D results. It is necessary to summarize the experience and methods to improve production efficiency.

(2) The requirements for computer hardware configuration are high. In this experiment, due to insufficient computer hardware configuration selected at the beginning, the aerial triangulation and the reconstruction of model often stops automatically. So it is necessary to choose a computer with appropriate hardware configuration.

It's believed that with the continuous progress of technology and the improvement of software, both of the above shortcomings will be well resolved. 3D modeling based on UAV oblique photogrammetry technology will play an increasingly important role in more fields.

6. References

[1] Yang Yanmei, Wang Ying, Shi Lei, et al. Construction of Fine 3D Models Based on DP Modeler [J]. Bulletin of Surveying and Mapping, 2021 (5): 106-110

[2] Liu Baohua, Wang Zhi, Song Yunji. Fusion Application of 3D Laser Point Cloud and Drone Oblique Model [J]. Bulletin of Surveying and Mapping, 2021 (6): 159-162

[3] Liu Hanhai, Fan Yuhong, Wang Debao et al. Unmanned Aerial Vehicle Survey Technology and Application [M]. Beijing: China Machine Press, 2020:121-129.

[4] Yu Lili. Research on Urban 3D Realistic Modeling Based on Drone Tilt Photogrammetry Technology [J]. Geomatics & Spatial Information Technology, 2021 (5): 86-88

[5] Du Jinli, Research on 3D Modeling Based on ContextCapture [J]. Geospatial Information. 2021 (5): 53-54.

[6] Zhang Huiying, Dong Chunlai, Wang Jigang, et al. Practice and analysis of 3D modeling of unmanned aerial vehicle oblique photography based on Context Capture [J] Bulletin of Surveying and Mapping, 2019 (S1): 266-269