Research on quality Inspection method of Topographic Map using oblique Photogrammetry

Yatong Chen¹,²,³,a, Jianjun Cao¹,⁴*b

¹Faculty of Geomatics, Lanzhou Jiaotong University, Lanzhou, Gansu
²National and Local Joint Engineering Research Center for the Application of Geographical and National Conditions Monitoring Technology, Lanzhou, Gansu
³Gansu Provincial Engineering Laboratory for National Geographic State Monitoring, Lanzhou, Gansu
⁴Gansu Provincial surveying and Mapping skills Identification and guidance Center, Lanzhou, Gansu

aemail: 378894205@qq.com
b*Corresponding author’s e-mail: 0618633@stu.lzjtu.edu.cn

Abstract. In view of the shortcomings of traditional methods in the quality inspection of large-scale topographic maps in Alpine area and high altitude areas, such as the difficulty of operation and the limited coverage of detection points, this paper puts forward the method of UAV tilt photogrammetry. This paper attempted to replace the traditional quality inspection method in the quality inspection of mathematical accuracy of large-scale topographic maps. By constructing the three-dimensional real scene model of the target area, this paper studied a new method for the quality inspection of mathematical accuracy of large-scale topographic maps. By breaking through the fixed mode that the traditional quality inspection can only be checked by on-the-spot collection, further improve the accuracy and objectivity of the results quality inspection, intensive manpower and material resources, and improve the efficiency and quality of the quality inspection work. Comparing with the traditional check points collected in the field, the UAV tilt photogrammetry method can replace the traditional quality inspection method in the quality inspection of mathematical accuracy of large-scale topographic maps.

1. Introduction
At present, the quality inspection of domestic topographic maps mostly adopts the mode of manual field inspection. This mode is an obvious dissipative structure, which uses time in exchange for space, and the consumption of a large amount of human and material resources in exchange for workload and work efficiency[1]. This method has obvious limitations, especially for situations such as complex topography and topography in high-cold and high-altitude areas, there are many problems in field collection such as insufficient data coverage and unsafe operations. With the increasing application value of UAV technology, the development and application of UAV in the field of geographic information product quality inspection has received more and more attention [2]. Feng Wei proposed the technical application of using unmanned aerial vehicles to survey complex terrain areas in high cold and high altitude [3]. Gao Zhiguo et al. [4], Liu Yujie et al [5] analyzed various applications of UAV tilt photogrammetry in topographic map measurement. The development of tilt photogrammetry
technology is now relatively mature, and a large number of scholars have conducted research on the various technologies it contains. Burt et al. [6] proposed the use of multi-band fusion method for color fusion along the seam line, and Gal et al. [7] proposed the use of standard Poisson fusion method for texture mapping. Görres J[8] had also done a lot of research on the production of tilt photogrammetric model results. In the existing related research, the accuracy of the three-dimensional model lacks authoritative indicators and basis, and the error propagation and analysis content for oblique photogrammetry technology is less. From the perspective of discipline integration, UAV tilt photogrammetry technology is mostly used in topographic map production, geological and mineral exploration, disaster emergency and other fields, and it is rarely applied in the field of surveying and mapping product quality inspection.

In this paper, a multi-rotor UAV is used to conduct tilt photogrammetry experiments in high-cold and high-altitude areas, and digitally analyze and process the elevation, plane, and texture information contained in the photographic aerial photos to construct a three-dimensional model product. By extracting the inspection data from the three-dimensional model, the quality inspection of the mathematical accuracy of the large-scale topographic map is completed, and the reliability of the above inspection method is judged by the traditional inspection results. The application of drone tilt photography technology to the field of topographic map quality inspection will make the inspection coverage more comprehensive under the premise of ensuring the accuracy of quality inspection, and greatly improve the efficiency and objectivity of quality inspection.

2. Materials and Methods

2.1. UAV tilt photogrammetry in alpine area

The high mountain area belongs to the difficult area in the topographic map quality inspection. If the tilt photogrammetry method can complete the topographic map quality inspection in the alpine area, it can also be completed in other areas in theory. Therefore, in this paper, the study area is chose in the high altitude area, the air is relatively thin and convective unstable, the topography is complex, the local height difference is large, the maximum height difference in the region is more than 200 meters, the conventional tilt photogrammetry scheme is no longer applicable. According to the specific situation of the study area, this experiment optimizes the tilt photogrammetry scheme as follows:

(1) The image control points in the study area are arranged in excess, the flight area is 1.2 square kilometers, a total of 116 image control points are set up, and the distance between image control points is shortened to 100 meters. In the area with large height difference, image control points are added at the top and bottom of the slope, and encrypted image control points are arranged in areas with complex topography or dense buildings to ensure the accuracy of the features.

(2) The geographical environment in the study area has particularity, in order to ensure the accuracy of all aerial photography indicators should be higher than the corresponding requirements of aerial photography standards. According to the regional characteristics, the flight strategy of lowering height is adopted to ensure the ground resolution, and the altitude is 80m-120m. At the same time, in order to ensure the accuracy of the results, the course overlap rate and side overlap rate are 80% and 75% respectively, the curvature of the route should be less than 5%, the altitude distance between the adjacent photographs of the same route is not more than 10m, and the distance between the maximum altitude and the minimum height is not more than 20m.

(3) In view of the area close to the mountain area and the large height difference, the flight strategy of multi-sorties is adopted, and the altitude of each block can be changed according to the requirements. If the accuracy or resolution of the aerial picture is insufficient in a single area, an additional route can be set up to make up the flight on the basis of the original route. The specific flight information is shown in Table 1.
### Table 1. details of flight information

| Region | Number of control points | Time (Day) | Aircraft | Number of flights | Notes |
|--------|--------------------------|------------|----------|-------------------|-------|
| 1      | 86                       | 6          | M600PRO  | 18                | Two flights were darker and heavy flights were carried out. |
| 2      | 30                       | 1          | M600PRO  | 4                 | Close to the mountain area, raise the altitude to fly. |

2.2. 3D modeling method

The basic idea of UAV tilt photogrammetry is to obtain image data by determining aerial photography scheme, image control point layout, route planning, flying using UAV and so on. The experiment takes the multi-view image data of tilt photogrammetry as the basic material, uses the reconstruction master software and Get3D automatic real-scene modeling system to complete the model generation, uses the SIFT feature matching algorithm to match the photos, Block Aerointegration by Bundle, closely matches the multi-view images, Construction of Triangulated Irregular Network (TIN), and then texture mapping, corrects the model, and generates the real photographic image from the collected true color aerial photos. The orthophoto images and local three-dimensional models of the experimental area are shown in Figure 1.

![Figure 1](image)

(a) Orthophoto image  
(b) Local of 3D model

2.3. Detection data extraction based on 3D Model

In the experiment, the DasViewer software is used to extract the point coordinate and the length of the model. There are 20 plane precision checkpoints and 30 elevation precision checkpoints in surveying in the field and 3D model. Theoretically, the checkpoints should be evenly distributed in the sample area. The traditional method of field check point collection is realized by manual field collection by means of GNSS, and the collection point has some limitations, especially for high cold and high altitude areas, some areas are too undulating, the geographical location is relatively remote, there are many problems, such as weak signal, operation danger and so on, so the collection points are relatively concentrated. On the other hand, the model checkpoints can be selected randomly and evenly, and the sampling points can be collected arbitrarily within the scope of the model construction, which improves the reliability and accuracy of the quality inspection. In this paper, in order to make the verification process more intuitive, the checkpoint extracted by the model is the same as the field mapping point. The distribution of check points is shown in figure 2. The process of checkpoint extraction is shown in figure 3.
2.4. Quality Test Theory of Mathematical accuracy of Topographic Map

Among them, mathematical accuracy and geographical accuracy mainly rely on field mapping, through the GNSS dynamic positioning method to obtain the corresponding checkpoints and feature points, by comparing with the corresponding data of the inspection results to determine the quality of the tested products. Among them, the quality level of unit achievements is reflected in percentage. In the classification of quality errors and omissions in large-scale topographic maps, mathematical accuracy includes three qualitative quantum elements: mathematical basis, plane accuracy and elevation accuracy, and the latter two evaluation criteria are moderate errors. Mathematical accuracy the scores of mass quantum elements are calculated by interpolation:

\[
S_{2i} = 60 + 40 \times \frac{\Delta m}{0.7 \delta_m} \tag{1}
\]

In the formula: \(S_{2i}\) is the score of the mass quantum element, \(\Delta m\) is the error limit difference of the mass quantum element and the error difference in the detection, and \(\delta_m\) is the error limit difference of the mass quantum element.

The score of quality element \(S_1\) was calculated by weighted average method. The value of \(S_1\) is calculated according to formula (2).

\[
S_1 = \sum_{i=1}^{n} (S_{2i} \times p_i) \tag{2}
\]

In the formula: \(p_i\) is the weight of the mass quantum element; \(S_1\) and \(S_{2i}\) are the mass element and the test score of the mass quantum element; \(n\) is the number of mass quantum elements contained in the mass element[9].

2.5. Testing method for mathematical accuracy of topographic maps

The inspection of mathematical accuracy in the quality inspection of large-scale topographic maps is usually completed by comparing the field field mapping data or model extraction data with the same name data in the topographic maps to be tested. The error test of the absolute position is carried out by the following methods, and the elevation accuracy calculation method is the same as the plane accuracy calculation method: if the plane detection point \(A (x_1, y_1, z_1)\) is set, and the same position point \(B (x_2, y_2, z_2)\) of the topographic map to be tested, the plane point difference \(D_s\) is

\[
D_s = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{3}
\]

In the process of quality inspection, the checkpoint data is usually regarded as the true value, then the error \(a\) in the plane is

\[
a = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (D_s^2)} \tag{4}
\]
The relative position accuracy of large-scale topographic maps is usually determined by the difference of edge lengths. If the coordinates of the two endpoints of edge LA, \( (x_1, y_1, z_1) \) and \( (x_2, y_2, z_2) \), the value of LA length is

\[
L_a = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}
\]  

(5)

The LA was compared with the homonym side length LB measured in the field. N groups of side lengths of the same name are randomly selected evenly in the sample range, and the error in the relative position of the results to be checked is \( e \).

\[
e = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (L_{a,i} - L_{b,i})^2}
\]  

(6)

3. Results & Discussion

3.1. Introduction to the research area
The experimental area is Langmusi Town, Gannan Tibetan Autonomous Prefecture (in Gansu Province). In the study area, the geomorphology is seriously divided, the vegetation coverage is large, the buildings in the residential areas are complex, and due to ethnic, religious and cultural factors, the courtyard has many high walls, and there are many unreachable and inaccessible areas, and it is difficult for the traditional quality inspection methods to collect data. It is easy to appear that the amount of testing data in the sample map is too small or too concentrated, which leads to the joint quality evaluation of various images and reduces the reliability of the quality inspection results.

3.2. Quality inspection of topographic maps by oblique photography
In the three-dimensional model, 20 plane accuracy checkpoints and 30 elevation accuracy checkpoints are collected, which are theoretically uniformly distributed in the sample map area. According to the corresponding specifications, the limit error of plane accuracy of topographic map to be tested is 0.6m, and that of elevation accuracy is 0.7m. The distribution of the two differences is shown in Fig. 4 (a) and Fig. 4 (b) respectively. The final test result is that the error of plane check point is 0.22 m and that of elevation check point is 0.21 m. The relative position accuracy test extracts 10 inspection edges from the topographic map and 3D model to be tested. The error in the relative position of the sample to be tested is 0.11 m.

\[\text{(a)}\text{Distribution of plane check point}\]
\[\text{(b)Distribution of elevation check points}\]

Figure 4 Distribution of check points

3.3. Verification of traditional quality inspection methods
By using the traditional quality element test method of mathematical accuracy of topographic map, 20 homonym points of 3D model and 30 homonym points of elevation accuracy are collected in the field. Theoretically, the checkpoints should be evenly distributed in the sample map area. The plane checkpoint difference comparison (figure 5a) and the elevation checkpoint height difference (figure 5b) are shown in figure 5. In the traditional test method, the plane error is 0.19m, the elevation error is
0.37m, and the relative position error is 0.12m. Referring to the relevant inspection standards, the error limit error of plane check point is 0.6 m, that of elevation check point is 0.7 m, and that of relative position is 0.2 m.

3.4. Result analysis

The tilt photogrammetry method is used to construct a three-dimensional model for topographic map quality inspection, and the inspection data can be randomly and evenly distributed in the inspection area, and the detection data can be extracted arbitrarily within the construction range of the model. the reliability and accuracy of quality inspection are improved. According to the improved defect deduction method model, the mathematical accuracy score of the quality inspection method of the three-dimensional model of tilt photogrammetry is 95.7; the mathematical accuracy score of the traditional method is 91.2, and the detection and verification results are excellent. From the verification results of the traditional methods, we can see that in the quality inspection results of topographic maps based on tilt photogrammetry, the difference between the accuracy of mass quantum elements and that of traditional methods is very small, and the median error is far less than the reference limit, and the accuracy is enough to meet the mathematical accuracy tests of mass quantum elements of 1:1000 large-scale topographic map.

4. Conclusions

In the quality inspection of large-scale topographic maps, the mathematical accuracy of tilt photogrammetry is close to that of traditional methods, and meets the requirements of relevant specifications. Only for the test of mathematical accuracy, the three-dimensional model test method of tilt photogrammetry can replace the traditional field mapping test method. At the same time, compared with the traditional quality inspection method, this method has the following advantages: (1) the three-dimensional model obtained by tilt photogrammetry can better represent the actual situation of the survey area, and can evenly select detection points in the survey area. Further improve the maneuverability and accuracy of topographic map quality inspection. (2) the overall working time is faster than the traditional method, the distribution of detection points is uniform, and the conclusion is more reliable.

At the same time, it also has some areas that need to be improved and further studied. The main results are as follows: (1) At present, there are no relevant standards for quality assessment of 3D models. How to ensure that the accuracy of 3D models generated by tilt photogrammetry meets the requirements of large-scale topographic map inspection needs to be further studied in the future. (2) In the production process of three-dimensional model of tilt photogrammetry, errors will be produced or enlarged in each link. How the error is iterated and transmitted, and what influence each error has on
the three-dimensional model, is also a problem that needs to be further studied in the future[10]. (3) The three-dimensional model has more obvious advantages than testing the mathematical accuracy of topographic map and geographical accuracy. How to combine the three-dimensional model to check the geographical accuracy of topographic map is the direction that the author is continuing to study.

Acknowledgments
Lzjtj(201806) EP support

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