APPLICATION OF UAV SYSTEM FOR LOW ALTITUDE PHOTOGRAMMETRY IN SHANXI

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ABSTRACT:

Recent years, as the urgent demands of the state and society for high-resolution aerial images and large-scale DLG (Digital Line Graphic), UAV borne low-altitude Photogrammetry system are used more and more widely. Combining the application of UAV system in Shanxi for collecting the 1:1000 scale DLG, in this paper, the main steps and key technologies of UAV system for lower altitude aerial photogrammetry are introduced.
In this passage, we took an area of Shanxi as the survey area, acquired 1024 aerial images of the survey area. After the calculation of aerial triangulation, we get the plane accuracy of the encrypted points is 0.21 m and the height accuracy of encrypted points is 0.35m, could meet the accuracy of 1:1000 scale mapping. It can be seen that the UAV system for low altitude photogrammetry has its own advantages in acquiring high resolution aerial images and large scale DLG, and UAV system has a great development prospects.

1. INTRODUCTION

Because of the flight altitude of the airplane and satellite is relative high, and the images acquired by them can not meet the accuracy of large-scale mapping, so if want to collect 1:1000 or even larger scale DLG, the only way is using the UAV borne low-altitude Photogrammetry system. Depend on its low flight altitude and slow flight speed, UAV system can obtain higher resolution aerial images, which can meet the accuracy requirement of large-scale mapping. In order to collect the 1:1000 scale DLG data of Shanxi, there are three main processing steps: aerial images acquisition and pretreatment; aerial triangulation and its accuracy assessment; stereo-mapping of the aerial image and accuracy assessment. After these processing steps, we can finally get the 4D products, including DRG、DEM、DOM and DLG, which can meet the needs of the state and society for all kinds of data.

2. AERIAL IMAGES ACQUISITION AND PRETREATMENT

2.1 Aerial images acquisition

In the UAV borne low-altitude Photogrammetry system, the flying platform usually is unmanned airplane or unmanned aircraft, its flying altitude is usually 300 m to 3500m, and its max flying speed is 120 km/h, max-endurance is about 4 hours. The GPS and IMU of the UAV system can record the rough exterior orientation elements. The sensor of the UAV system is non-metric digital camera. In general, the size of images acquired by a single digital camera is usually small, and the amount of the aerial images which should be processed is usually very large. Comparing with processing large size images, it will need much more time to process the images acquired by a single digital camera, but the arising of composite camera can largely make up this weakness. The aerial images acquired by composite camera can be spliced to a large image, so the amount of aerial images to process will be much smaller and the efficiency of image processing can be greatly improved. For Instance, the size of the digital image acquired by a single Cannon 5D Mark II is 5616*3744 (pixels), while the size of the images acquired by composite four camera can be 7500*7500 even larger, so using composite four camera can greatly improve the processing efficiency. Usually, there are two kinds of composite cameras: composite double camera and composite four camera. Before aerial triangulation processing, it is necessary to splice the images by composite cameras into a large image for reducing the workload. As shown blow , it is our developed composite double camera and composite four camera.

Figure1 Composite double camera Composite four camera

2.2 Aerial images pretreatment

Every digital camera has optical distortion, and optical distortion is an important error which could affect the quality of pixel coordinate. The optical distortion error can be divided into two categories: radial distortion and eccentric distortion. The radial distortion is always caused by Imperfect Lens Shape, it only relates to the distance the pixels far away from the principal point pixel, and the distance cause the pixel's position

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deviating from the ideal position along the diameter direction. According to positive and negative of the coefficient, the radial distortion can be divided into the barrel distortion and pincushion distortion.

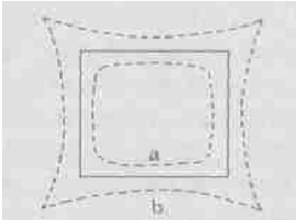

Figure 2 Distortion model of the camera

As shown in the above figure, the solid square represents the pixel position without distortion, the dotted line a represents the error of barrel distortion, every point except principal point shrink towards the principal direction. The dotted line b represent the error of pincushion distortion, every point except principal point expands towards the negative principal direction. Because radial distortion is the main component of the distortion, so the distortion discipline of the radical distortion can basically reflect the distortion discipline of the camera, and we can improve the image's quality by eliminating the radical distortion.

Because the distortion can affect the accuracy of stereo-mapping, it is very important to rectify the image's distortion by the distortion model. The mathematical model of the radial distortion is as formula 1:

$$\begin{aligned}\Delta x &= \bar{x}r^2k_1 + \bar{x}r^4k_2 + (2\bar{x}^2 + r^2)p_1 + 2p_2\overline{xy} + b_1\bar{x} + b_2\bar{y} \\ \Delta y &= \bar{y}r^2k_1 + \bar{y}r^4k_2 + 2p_1\overline{xy} + (2\bar{y}^2 + r^2)p_2\end{aligned} \quad (1)$$

In the above formula, the origin of the coordinate is the left top corner point of the image, the x axis parallels the line of the image and the y axis parallels the column of the image. In the formula $\bar{x} = x - x_0$, $\bar{y} = y - y_0$, $r = \sqrt{\bar{x}^2 + \bar{y}^2}$, and (x_0, y_0) is the principal points of the image, k_1, k_2 is the radial distortion coefficients, p_1, p_2 is the tangential distortion coefficients, b_1 is the non-square factor, b_2 is the non-orthogonal distortion coefficient of CCD arrays arrangement. Then, we can use the error equation of the bundle adjustment with additional parameters to solve the inner orientation elements and distortion coefficient.

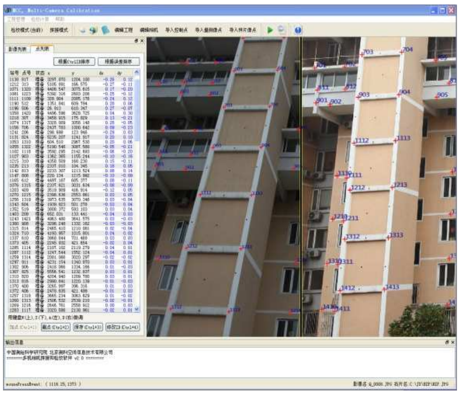

Figure 3 multi cameras calibration software MCC

In order to calibrate the digital camera and rectify the distortion of the images, we found a control field and develop the multi cameras calibration software MCC (as Figure 3) to calibrate the inner orientation elements and the distortion parameters. Using more than 1000 control points, MCC can calculate the accurate inner orientation elements and distortion coefficients.

According to the distortion parameters, we can rectify the distortion of the digital images, this is a very important step for the further processing of aerial image.

3. AERIAL IMAGE'S AERIAL TRIANGULATION AND ACCURACY APPRAISEMENT

After acquiring and rectifying the aerial images and before stereo-mapping, a very important step is the aerial triangulation of aerial images. In this step, we need to calculate the accurate exterior orientation elements and the coordinate of the tie points, and finally generate the DEM and DOM data of survey area, DEM and DOM can be the final achievement. Besides, appraising the accuracy of the aerial triangulation is also a very important job, the accuracy of the aerial triangulation calculation result can represent the quality of the DEM and DOM data, also represent the quality of the processing software.

3.1 Aerial image's aerial triangulation

In order to calculate the accurate exterior orientation elements and the coordinates of the tie points, we develop the aerial triangulation processing software MAP_AT, it is very suitable for UAV borne low-altitude Photogrammetry system. The main processing steps in MAP-AT include automatically automatically creating the stripes, relative orientation of single model, connection of a single stripe, connection of different stripes, bundle adjustment calculation of the free network, absolute orientation of the free network and generating and editing DEM and generating DOM.

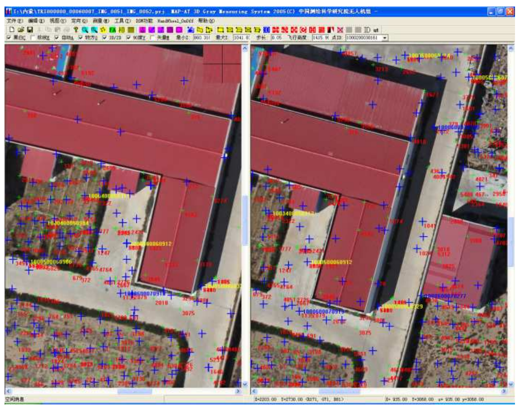

Figure 4 MAP-AT aerial triangulation software

The remarkable characters of MAP-AT is high degree of automation, strong ability of handling large angle aerial images, large amount points to participate in the adjustment calculation and accurate calculation result. As shown in the Figure 4, there will be more than one hundred orientation points in every image for the calculation of relative orientation, which could guarantee the accuracy of relative orientation as much as possible. It is almost do not need any manual operation, most of the processing steps is done automatically. After founding the free net of the whole survey area, we use 106 ground control points to carry out the absolute orientation, as shown in Figure

5, is measuring the ground control points for the absolute orientation in the MAP-AT.

Figure 5 Measuring GCP in MAP-AT

During the processing of aerial triangulation, most of the steps need adjustment calculation so most of the gross error points can be eliminated as much as possible, at last we can get the accurate aerial triangulation result. In this paper, we acquire 1024 aerial images of 12 aerial stripes in the survey area and the resolution of the aerial images is 0.1m. After the relative orientation, we use 106 ground control points to achieve the absolute orientation. Finally, we get the plane accuracy of the encrypted points is about 0.21 m and the height accuracy of encrypted points is about 0.35m.

3.2 Accuracy appraisement of aerial triangulation

After the above processing, we can obtain the single DOM corresponding to every aerial image, as the achievement data ,we should splice the single DOM into a large DOM which include the entire survey area and the spliced DOM is one of the final achievement. The following figure is the DOM of the survey area.

Figure6 DOM of the survey area

During the process of aerial triangulation, we have got the accurate exterior orientation elements and the coordinate of the tie points. Before the stereo mapping, it is also very important to appraise the accuracy of the aerial triangulation results. The most common method is to find some check points of the survey area to test the accuracy of the aerial triangulation results. The check points should be be evenly distributed in the survey area. In this paper , we use 13 check points of the survey area, which is evenly distributed in the survey area, to test the accuracy of the aerial triangulation, and table 1 is the residuals table of the check points.

Check point No	X error	Y error	Z error
k1	0.291	-0.108	-0. 242
k2	-0.163	0.114	-0.228
k3	-0.184	-0.206	-0.278
k4	-0.189	-0.213	0.325
k5	-0.212	-0.124	-0.297
k6	0.208	0.154	-0.128
k7	0.197	0.211	-0.232
k8	-0.224	0.209	0.251
k9	0.241	-0.245	0.342
k10	-0.167	0.167	-0.292
k11	0.206	-0.157	0.112
k12	-0.198	0.147	-0.227
k13	0.206	0.242	0.195

Table 1 the Residuals table of the check points

As shown in the table 1, we can calculate the average mean square error of X coordinate of the check points is 0.209m, the average mean square error of Y coordinate is 0.182m and the average mean square error of Z coordinate is 0.261m. We can see that the residuals of the check points smaller than tolerant residuals, so the accuracy of the aerial triangulation can fully meet the requirement of 1:1000 scale mapping.

4. AERIAL IMAGE'S STEREO-MAPPING AND ACCURACY APPRAISEMENT

4.1 Aerial image's stereo-mapping

After the processing of aerial triangulation, we have calculated the accurate exterior orientation elements of every aerial image. With the calculated exterior orientation elements, we can do the mapping in the three-dimensional condition.
For the stereo-mapping of the aerial images, we developed stereo-mapping software MAP_LCS. MAP-LCS is very suitable for the stereo-mapping of the aerial images acquired by the UAV system. Because the amount of stereo-models is usually large, so changing the stereo-modal is a cumbersome process in the common stereo-mapping software, while in the MAP_LCS system, we can import all the stereo models of the survey area at the same time, and conveniently change the model to be mapped just by moving your mouse to the boundary of the window. This feature can greatly improve the efficiency of stereo-mapping. Another feature of MAP-LCS is that its symbol library has a wealth of surface feature symbol, you can find almost every common surface feature symbol in the library and draw a variety of the surface features accurately in the large scale topographic maps by using these symbols. Besides that, MAP-LCS is able to generate high quality contours

automatically, only need little operation to edit it. It is also very easy to use and if you are skilled with MAP-LCS, the efficiency of stereo-mapping will rather high. As Figure7, is MAP-LCS software.

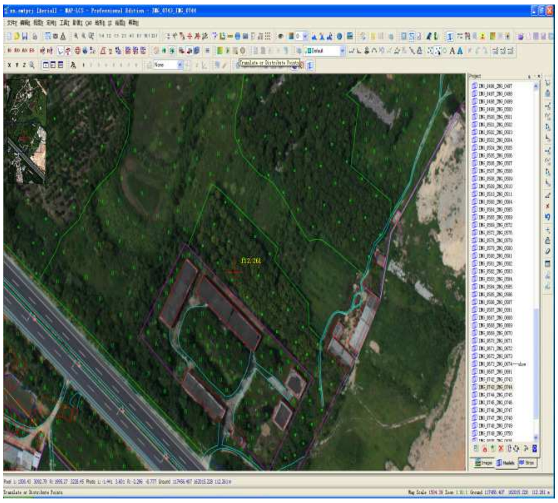

Figure 7 MAP-LCS stereo-mapping software

4.2 Accuracy appraisement of mapping

Appraising the accuracy of mapping the last step of the data processing and also is a very important step for us. The DLG is one of the final achievements and its accuracy determines its quality. For appraising the accuracy of the DLG, we use GPS to survey 15 obvious features in the survey area to test its accuracy of mapping. As shown blew is the residuals table of the stereo-mapping.

Feature No	X error	Y error	Z error
p1	0.252	-0.147	-0. 311
p2	-0.241	0.208	-0.298
p3	-0.192	-0.224	-0.312
p4	-0.203	-0.2276	0.324
p5	-0.236	-0.188	-0.268
p6	0.185	0.231	-0.301
p7	0.217	0.255	-0.195
p8	-0.302	0.301	0.294
p9	0.232	-0.178	0.334
p10	-0.181	0.207	-0.361
p11	0.210	-0.243	0.188
p12	-0.199	0.271	-0.356
p13	0.249	0.264	0.299
P14	0.301	-0.196	-0.316
P15	0.291	0.291	0.321

Table 2 the mapping residuals table of the control points

As shown in the above Table, we can calculate he average mean square error of X coordinate of the 15 feature points after stereo-mapping is 0.236m, the average mean square error of Y coordinate is 0.223m and the average mean square error of Z coordinate is 0.303m.Through the stereo-mapping residuals of the 15 feature points ,we can draw the conclusion: the accuracy of DLG the we have acquired can meet the requirement of 1:1000 scale mapping, so it is feasible to use UAV borne low-altitude Photogrammetry system for collecting large-scale vector topographic maps.

5. CONCLUSION

According to the collection task of DLG data in Shanxi, this paper introduces the main processing steps and key technologies in the UAV borne low-altitude Photogrammetry system. Through the aerial triangulation processing to the 1024 aerial images of the survey area, we calculate the plane accuracy of the tie point is 0.21m and the height accuracy is 0.35m. Besides that, we use 15 check points to test the accuracy of the stere-mapping and finally calculate the average mean square error of X coordinate of the 15 feature points is 0.236m, the average mean square error of Y coordinate is 0.223m and the average mean square error of Z coordinate is 0.303m, which can completely meet the accuracy of 1:1000 scale mapping. This paper fully show the advantage of the UAV borne low-altitude Photogrammetry system in acquiring the high resolution aerial images and large scale DLG. The UAV system still has a large potential in the further development.

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