Actualize of Low Altitude Large Scale Aerophotography and Geodesic base on Fixed-wing Unmanned Aerial Vehicle Platform

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ABSTRACT:

This paper introduces the key technologies and methods of establishing the aerial photogrammetric system using Unmanned Aerial Vehicles (UVA) photogrammetry technique for satisfying the increasing need of fast acquiring aerial data. It also introduces the design, research and production of UVA platform for the demand of aerial photogrammetry. Finally, it is demonstrated that the feasibility of photogrammetry with this UVA system through researching the key technique points of photogrammetric procedures and analyzing the accuracy of experimental results.

1. INTRODUCTION

At present, Chinese urbanization is speeding up, urban construction scale is expanding rapidly. With the fast construction of small towns and new development of new rural areas, a large number of medium-sized towns and small villages need surveying and mapping services. Because of longer period, high cost, lower economic benifits, the existing aerial photography is generally difficult to undertake such tasks.

In order to resolve this problem, Beijing Huabei Optical Instrument Co., Ltd and Beijing Institute of Surveying and Mapping joined together to develop low-altitude remote sensing based on fixed-wing UAV platform for aerial photography system. This system has advantages such as flexible movement, quick response, high efficiency, so it can fill in the blank of large-scale aerial photography.

This paper will introduce and explain the key technologies of establishment this system, and analyzes and demonstrateds the feasibility of its application in aerial photography production.

2. DESIGN AND RESEARCH OF UAV PLATFORM FOR PHOTOGRAPHY

In order to meet the strict requirements of UVA used in photographic measurement, it must have a comprehensive design and integration of overall layout, aerodynamic performance, control methods and equipment and safety of the aircraft.

During design of UVA, after a large number of flight tests of different layout aircrafts, finally V structure is adopted(Figure 1), this kind of layout aircraft has the advantages of short-range for taking off and landing, high load capability, good flight control and simple structure.

The aircraft manufacturring uses high-quality glass fibers and carbon composition, it enhances the strength and rigidity of the body and the same time reduces the weight of the aircraft, which is helpful to provide greater carrying capacity. The aircraft has excellent aerodynamic performance and reliability through using various high-precision molds.

Figure 1. Outlook of UVA

Aircraft's power system adoptes the advanced international UVA aviation gasoline engine. This engine has double cylinders and parallel installation, so it has small vibration , big power output, stable and reliable operation, which furtherly enhances the reliability of the aircraft.

Flight control system adoptes the advanced international UVA autopilot as the core component. Through the second development for autopilot, it improves the flight control algorithms and processes, which can meet the requirement of measurement. Autopilot simultaneously recordes images of the orientation elements, as a follow processing reference.

Manipulation control of the aircraft uses UVA dedicated service manufactured by titanium alloy. This dedicated service has great output, fast response, slowdown part without gaps, so it provides a reliable guarantee for the aircraft autopilot response to the further stability control.

Aerial photography device adoptes civilian professional digital SLR camera. This camera uses whole image sensors with more than 10 million pixels and the image resolution is 0.008mm. The memory card is used as a storage medium. In accordance with the specific for the identification, aerial camera has been measured with the accurate focal length, image distortion and other various parameters. In order to furtherly enhance the precision of the camera, so two-dimensional cloud terrace are designed (Figure 2). Following flight tests prove that after using this cloud terrace, the image accuracy is improved effectively.

Figure 2. Outlook of Camera

In terms of software, we developes a flight mission planning software by ourselves in order to make UVA system more suitable for aerial photographic measurement (Figure 3). This software can automatically output flight documents including flight routes and photographic exposure coordinate according to mapping resolution, overlap of images, measured zone coordinates these photography parameters. And can also submit flight reports, which is helpful to know the basic flight information in advance. For example, requirements of flight time, flight mileage, and total number of aerial photography photoes. When it is flying, the flight document is put on the autopilot, the aircraft can automatically work according to planning flight routes, exposure point and can avoid complicated manual planning work, which improves the efficiency and reduces the man-made errors.

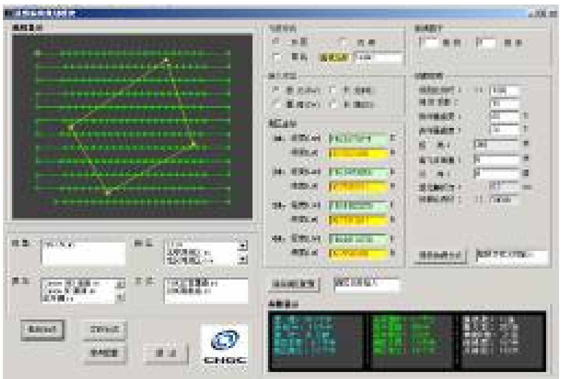

Figure 3. Flight Mission Planning Software

In order to enhance the reliability of UVA aerial photography, we developes a image quality inspection software after analyzing the autopilot records of orientation elements. This software can automatically arrange with flight routes, exposure points according to the form of recording the position of elements. After finishing aerial photography, visual inspection diagram is applied to recording and displaying the overlapped images, size, and photographic consistency. If there's anything wrong, it can fly again, which improves the quality and efficiency of fieldwork.

For the requirement of using UVA in bad ground conditions or flight safety requirement for city, the developed launch system (Figure 4) for UVA, is installed and furtherly enhances the venue of the adaptability and security of UVA, which enlarges the application of UVA. At the same time, UVA system equipped with digital wireless data transmission system, operators can monitor all kinds of conditions of UVA anytime. Adjustment methods for various flights tasks greatly improves the operation flexibility and safety.

Figure 4. Launch System

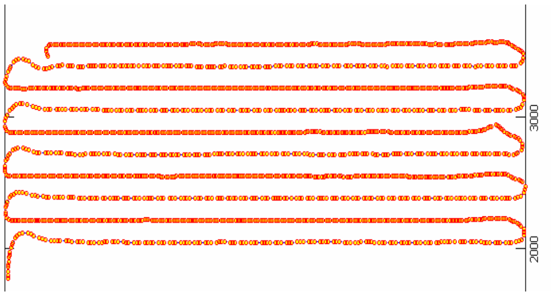

Figure 5. UVA's Flight Typical Track Map

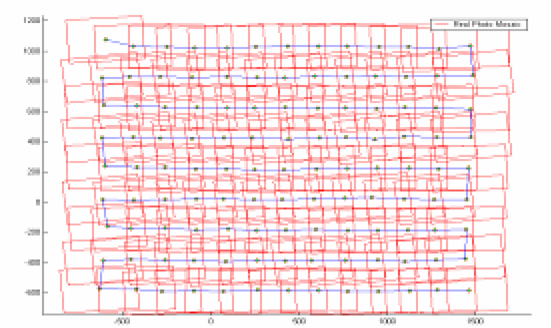

Figure 6. Image Diagram

UVA photography platform performance indexes are listed in Table 1:

<table>
<tr><th colspan="2">UVA performance index</th><th colspan="3">Flight control system performance index</th></tr>
<tr><td>Takeoff weight</td><td>20Kg</td><td colspan="2">Aerial height steady ability</td><td>±5m</td></tr>
<tr><td>Maximum load</td><td>6 Kg</td><td rowspan="3">Steady ability</td><td>Pitching angle</td><td>-1.2º～1.2º</td></tr>
<tr><td>flight time</td><td>3hours</td><td>Rolling angle</td><td>-1.5º～1.5º</td></tr>
<tr><td>Distance of takeoff and landing</td><td>30m-50m</td><td>rotating angle</td><td>-5º～5º</td></tr>
<tr><td>Cruise speed</td><td>100-110Km/h</td><td colspan="2">Course exursion</td><td>±2 米</td></tr>
<tr><td>Maximum anti-wind ability</td><td>6scale</td><td colspan="2">Exposure control</td><td>Auto-control</td></tr>
<tr><td>Maximum height</td><td>3000m</td><td colspan="3"></td></tr>
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Table 1. UVA Photography Platform Performance Indexes

In order to test the feasibility of using UVA platform to get aerial photographic information, the aerial triangulation analytical methods are applied to analyzing and evaluating the aerial photography information. And improvement suggestion is acquired based on these steps and the main suggestion including flight stability, anti-vibration, wind resistance, control of exposure time and maintainment of flight attitude angle ω、φ、κ capacity. Then flight control gets further improvement. The increased functions includes turning the buffer and exposure delay compensation, ensuring to get aerial photos to meet aerial survey requirements. The typical UVA's flight track map is shown in Figure 5 and the images diagram is shown in Figure 6.

3. UVA AERIAL SURVEY MAPPING EXPERIMENTS

UVA aerial survey mapping experiments include seting control point, aerial triangulation mapping and precision analysis.

3.1 Overview of aerial information

Experimental area is located in Beianhe town, Haidian District, Beijing, with area of 1.5 square kilometers, 7 flight routes and 56 photo pairs. Focal length equals to 35.470mm, image central point coordinations are x=35.800mm, y=23.900mm, and photography scale is 1:10000. Experimental image diagram is shown in Figure 7:

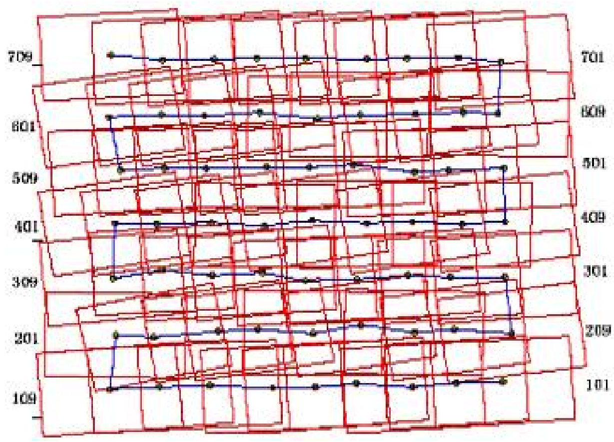

Figure 7. Experimental Image Diagram

According to the measure data of UAV platform equipment, the quality parameters of aerial photography at Beianhe experimental area are listed in Table 2.

Parameters	Maximum	Minimum	Average
Strip Deformation	5m	0m	2.5m(0.25%)
Rotating Angle	6.235°	0.055°	3.155°
Flight Altitude	355.069m	349.675m	351.359m
Longitudinal Overlap	69.12%	57.75%	65.31%
Lateral Overlap	36.48%	33.27%	35.21%

Table 2. Quality Parameters of Aerial Photography with UVA

3.2 Setting Control Point

According to the experiments, the results can be concluded that: Large number of air photo pairs, small overlaped areas of UVA aerial photography data guarantee the encrypt accuracy. By experiment and comparison, we choose a way which is like the standard air-line scheme to set control points. We set 32 control points in this experimental area homogeneously, and there are 20 planes & elevation points,12 elevation points. Scheme of setting control points is listed in Figure 8.

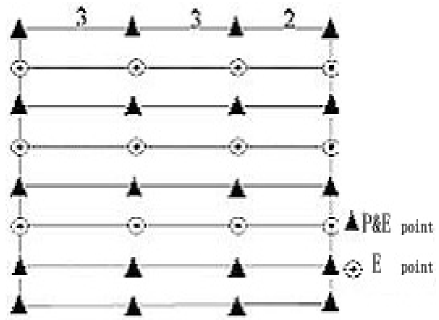

Figure 8. Scheme of Setting Control Points

3.3 Aerial Triangulation Analysis

Aerial triangulation analytical software is VirtuoZoAAT+PATB. Because of the problems such as small image scale, large number of air photo pair,short baseline, rotation and excursion of aerial photogrammetry bigger than traditional ones, low overlapped ratios, etc, it is difficult to pick up link points automatically in the procedure of aerial triangulation analysis.

Results of aerial triangulation analysis in Beianhe experimental area is in Table 3.

Aerial Triangulation	Mean Square Error of Control Points		Mean Square Error of Checking Points	
	Flat	Elevation	Flat	Elevation
Photogrammetric control tolerance	0.50	0.22	0.88	0.38
Result of survey adjustment	0.16	0.06	0.10	0.16

Table 3. Results of Aerial Triangulation Analysis in Beianhe Experimental Area

According to the table results, we can see that the accuracy of the results of aerial triangulation analytical in Beianhe experimental area meets the requirements of《Standard of City Surveying》(CJJ8-99) for encoded results of 1:2000 maps.

3.4 Mapping and Accuracy Analysis

We uses VirtuoZo to do the topographic plotting for 1:2000 digital line graph (DLG) in Beianhe area. After that, the accuracy inspecting and error analysis is applied to validating the results of topographic plotting using field polar coordinate method. 102 validating samples are selected in this area. The results of the sample error distribution is shown in Figure 9 :

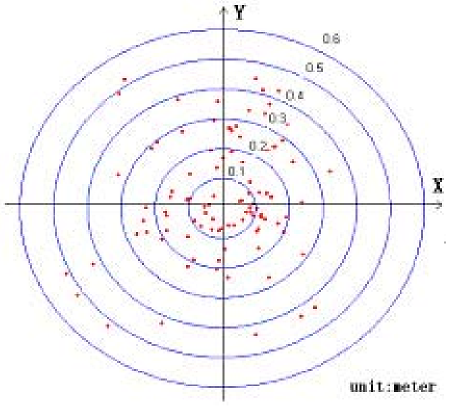

Figure 9.Error Distribution

Figure 9 reveals that the biggest error is no more than the 1m tolerance, and 95% of sample errors are less than 50% of the tolerance. And the sample errors basically conform the normal distribution with mean square error is ±0.246m.

Based on the accuracy analysis, we can use the fixed-wing Unmanned Aerial Vehicle platform to do the aerial photogrammeric plotting. The accuracy is completely satisfied the standard of urban surveying specifications.

4. CONCLUSIONS

By researching on the UVA photogrammetry techniques, we establish UVA photogrammetry system, test and verify the feasibility of this system for producing large scale aerial photogrammetric map. Functions such as automatical navigation, flight control, realtime transfer of survey and control data, automatical control of fixed point exposure of aerial photography device, air line planning, Real time man-machine interactive and realtime bug detecting and warning, is at the first level at home and abroad, and is most advanced internationally.

This technique makes it possible to bring unmanned technique into surveying and mapping manufacture. By using the UVA, it also takes the first place in bringing about the whole process of aerial photogrammetry. The establishing of UVA photogrammetry system provides a high efficiency、low cost surveying and mapping measure for the new development of new rural areas.

The UVA photogrammetry technique is still on the initial stage, by making further efforts to solve the problems such as loading big scale/multi-lens camara,high accuracy locating and control system,we will make UVA photogrammetry technique used more widely in the field of aerial photogrammetry.

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