

UAV FOR MAPPING —LOW ALTITUDE PHOTOGRAMMETRIC SURVEY

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ABSTRACT:

Two kinds of platform are accepted for mapping UAV system. One is remotely-piloted aircraft. Another is unmanned helium airship. A super-wide-angle camera is constructed by four digital cameras, mounted in different optical axis directions. A high accuracy calibration method is used to make compensation for the deformed errors due to the light and simple constructed mechanical frame. According to the feature of data get from the UAV acquisition system, a special aerial triangulation program has been developed. The DSM is automatically generated by image matching and TIN interpolation. It needs a little manual interaction operation to separate the points upon the building or lie down at grand for generation DEM. The DOM is also produced automatically based on the orientation elements and DEM results. As a research results, the UAV mapping system MAP-UAV has carried out several experiments.

1. INTRODUCTION

Over the last few years remote sensing technology has advanced in leaps and bounds. So much so that today it has far outgrown the capabilities of its two main carriers, the satellite and manned aircraft. With the fast growing need for highly accurate and detailed observation data required in fields such as environmental, agricultural and natural resources monitoring, image quality and accuracy gained via satellites is far from adequate. Also, data collection can be extremely slow and is only possible under cloudless conditions. Although manned aircraft offer sufficient resolution and accuracy, they are expensive and have a limited endurance of only a few hours.

The limitation of satellites and manned aircraft are high launch/flight costs, slow and weather-dependent data collection, restricted manoeuvrability, limited availability, limited flying time, low ground resolution ... (Pegasus 2004)

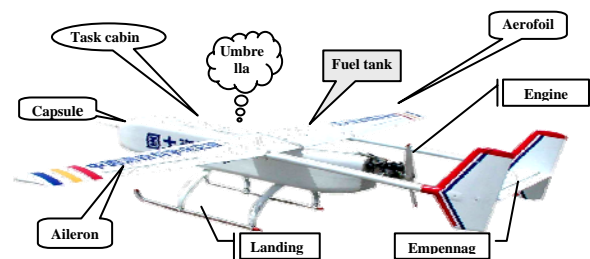
As an efficient supplement to remote sensing data collection from satellites and manned aircraft, UAV image acquisition technologies have been developed.

From the application point of view, there are two kinds of UAV remote sensing technology need paying attention especially. One is high altitude remote sensing in stratosphere. Another is low altitude UAV photogrammetric survey. Pegasus has introduced the technology of UAV remote sensing in stratosphere on the 20th ISPRS congress. In this paper, we only introduce low attitude UAV photogrammetric survey.

The reasons to develop the technology of UAV for low altitude photogrammetric mapping are as follows: 1) to perform very low altitude aerial photography at cloudy day, 2) to get full image of city building form different direction by complicated flying, 3) to supply a cheap and easy system for engineering organization for high frequency needs of aerial photogrammetric survey.

2. PLATFORM

Two kinds of platform are accepted for mapping UAV system. One is remotely-piloted aircraft. Another is unmanned airship. The useful load required is up to 15 kg. The photographic flying height is between 100 and 4000 meters, with speed 18—160 kilometres per hour. The remote pilot has both manual remote operation and automatic programming control functions. A simple constructed two dimensional stabilization plant are designed to keep the image sensor's optical axis directed at vertical.



Length of Aircraft	2.8m	Take-off Weight	50Kg
Wingspan	3.6m	Size of Task Cabin	300mm×500mm×300mm
Take-off Speed	70km/h	Speed	70~160km/h
Task Load	>8kg	Navigation Precision	≤80m
Aviation Time	3~4h	Control	Program-controlled, remote-controlled, self-control
Radius of Control	50km		
Height of aviation	100m~4000m		

Figure.1. picture of unmanned aircraft

Figure 1 shows the unmanned aircraft for low altitude photogrammetric mapping.

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3. SENSOR SYSTEM

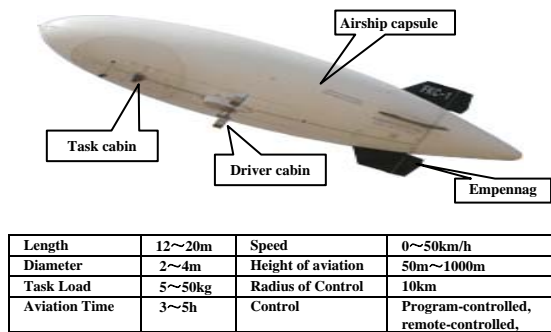


Figure2. picture of helium airship

Figure 2 shows the helium airship for low altitude photogrammetric mapping.

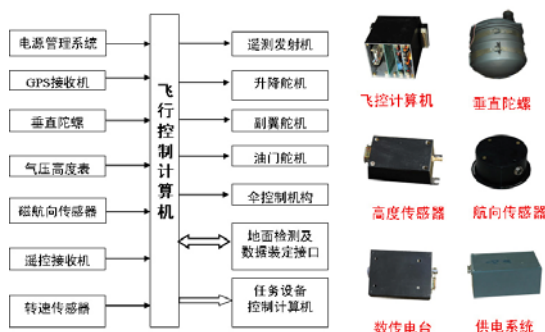


Figure3. flying control system and equipments

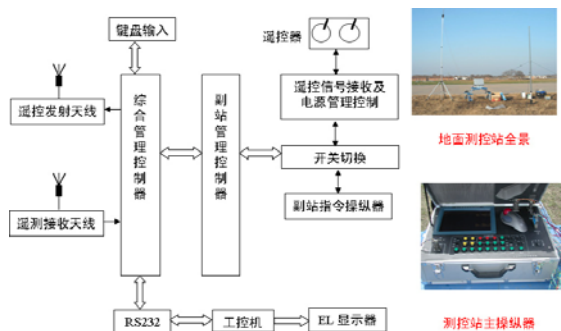


Figure4. remote ground station and equipment



Figure5. data communication and monitoring system

Figure 3, 4 and 5 show the flying control, data communication and grand monitoring equipments, same for the both platforms.

A super-wide-angle camera is constructed by four digital cameras, mounted in different optical axis directions. The four images taking from different cameras are special designed to have some overlapping areas, which used for high accuracy calibration of relative orientation elements between the four cameras to make compensation for the deformed errors due to the light and simple constructed mechanical frame. The geometric optical distortions from each camera are accurately calibrated. The advantages in using super-wide-angle camera are as follows: 1) to get large framed images at very low altitude flying for rising the production efficiency, 2) to enlarge the base to height difference at terrain.

Due to the limited efficient load of UAV platform and in order to keep the system to be easy, only general purpose digital camera are accepted and the installed stabilization plant are in low accuracy, but due to the possibility of very low altitude flying of UAV, this photograph system can acquire very high resolution images. To sum up the advantages and disadvantages of UAV data acquisition system, the UAV images are suitable for large scale mapping and routine monitoring.

Figure 6a, b show the super-wide-angle camera constructed by four digital cameras.



Figure6. a, b the appearance and inside of super-wide-angle camera

Figure 7 shows the overlapping structure of the images projected from the four camera data.

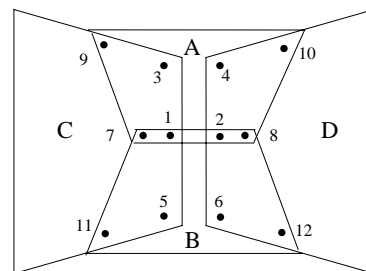


Figure7. overlapping structure of the images projected from the four cameras

In figure 7, point $i = 1, 2 \dots 12$ are selected for high accuracy calibration of relative orientation elements between camera A, B, C, D. The mathematical formulas have been derived as following.

The error equations for parallax (Δx , Δy) at point 1 from camera A and C is:

$$\begin{aligned}
 V_{1AC}(x) &= \Delta Ax - \Delta Cx + (f + \frac{x_A^2}{f})\Delta\varphi_A - (f + \frac{x_C^2}{f})\Delta\varphi_C + \frac{x_A y_A}{f} \Delta\omega_A \\
 &\quad - \frac{x_C y_C}{f} \Delta\omega_C + y_A \Delta\kappa_A - y_C \Delta\kappa_C - \Delta x_{AC} \\
 V_{1AC}(y) &= \Delta Ay - \Delta Cy + \frac{x_A y_A}{f} \Delta\varphi_A - \frac{x_C y_C}{f} \Delta\varphi_C + (f + \frac{y_A^2}{f})\Delta\omega_A \\
 &\quad - (f + \frac{y_C^2}{f})\Delta\omega_C + x_A \Delta\kappa_A - x_C \Delta\kappa_C - \Delta y_{AC}
 \end{aligned} \quad (1)$$

where, Δx_{AC} , Δy_{AC} are the parallax observation values obtained by least square matching of images from A and C; ΔAx , ΔAy , ΔCx , ΔCy are the deviation values of the optical centre of A and C; x_A, y_A, x_C, y_C are the image coordinates of point 1 projected from A and C; f is the principle distance of the cameras; $\Delta\varphi_A$, $\Delta\omega_A$, $\Delta\kappa_A$ and $\Delta\varphi_C$, $\Delta\omega_C$, $\Delta\kappa_C$ are the errors of φ , ω , κ of A and C need to be collected.

The error equations for point 2, 3...12 with other overlapping structure from B-C, A-D, B-D and A-B can be derived similarly.

The following condition equations are accepted

$$\begin{aligned}
 \varphi_A + \varphi_B &= 0 \\
 \omega_C + \omega_D &= 0 \\
 \kappa_A + \kappa_B + \kappa_C + \kappa_D &= 0
 \end{aligned} \quad (2)$$

From the equation (1) and (2), the $\Delta\varphi_A, \Delta\omega_A, \Delta\kappa_A, \dots, \Delta\varphi_D, \Delta\omega_D, \Delta\kappa_D$ can be solved. Thusly, the deformed errors due to the light and simple constructed mechanical frame can be compensated. The remained error is less than 0.4 pixels. This method is important for reducing the weight of sensor system making possibility to be accepted by UAV mapping.

Figure 8a, b, c, d and figure 9 show the images taking from camera A, B, C, D and the equivalent image constructed by above mentioned method.

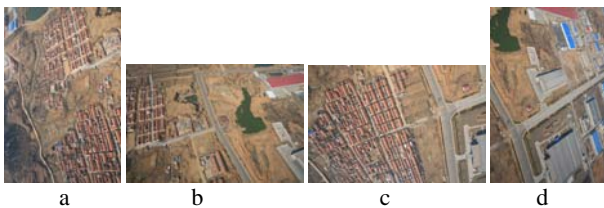


Figure8. a, b, c, d are the images taking from camera A, B, C, D



Figure9. the equivalent image of above 4 images

4. PHOTRGRAMMETRIC PROCESSING

4.1 Aerial Triangulation

According to the feature of data get from the UAV acquisition system, a special aerial triangulation program has been developed. The advantage features of this software are as follow: 1) Making high precision calibration for the geometric distortion from normal purpose used digital cameral. 2) Using Pos or GPS data combined with image matching to reconstruct the topologic relation of the images along the flying direction and between the neighbouring lines. 3) All the points in the triangulation network are selected and measured fully automatically (Figure10.). 4) multi-view geometric relations of the images are solved by large block adjustment with least square method (Figure11.). 5) The coarse error are detected full automatically by large number of redundant observations. 6) The result of orientation elements and control points are calculated through alternative solution to achieve 1:2000, 1:1000 or 1:500 scale mapping standard.

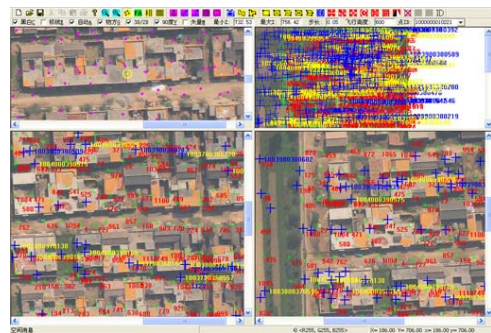


Figure10. select and measure the observed points fully automatically



Figure11. multi-view geometric relations of the images

4.2 DEM Production

After aerial triangulation the multi-view images are reorganized to be divided automatically into basic units as the stereo pairs in traditional photogrammetry. Then the DSM is automatically generated by image matching and TIN interpolation within every unit. It need a little manual interaction operation to separate the points upon the building or lie down at grand for generation DEM. ALL units are link up to form fully coverage DEM (Figure12.).

4.3 DOM Production

The DOM is also produced automatically based on the orientation elements and DEM results. Because 80 percent overlapping along flying direction have acquired from aerial-photography, only the centre part of image in the frame have been taken to be rectified into orthophoto imagery(Figure13.).

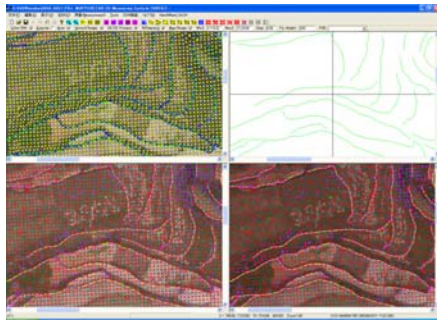


Figure12. the generation of DEM



Figure14. Huishui of Guizhou province



Figure13. orthophoto imagery

5. EXPERIMENTS

As a research result, the UAV mapping system MAP-UAV has carried out several experiments.

An experiment of digital orthophoto map production has been carried out in Guizhou province (Figure14.). The experimental area has 38 square kilometres with 1100 meters height above sea level. It is an agriculture area. The produced digital orthophoto maps have achieve the standard 1:2000 precision, which have been applied to land administration.

An experiment of 1:500 scale orthophoto productions has been carried out at Guangzhou downtown with 1 square kilometre. The products have been applied to urban planning (Figure15.).

An experiment for three dimensional modelling of city building has been carried out at Weihai City (Figure16.). The downtown area is 61 square kilometres. More than 20,000 buildings' three dimension model are constructed. And the result can be observed with Virtual reality system. And it also has been applied in urban planning.

6. CONCLUSION

The study on above prove that, to solve the question of limitation about load of UAV platform, we can design the light and small combined super-wide-angle camera which has the self-calibration function to construct the practical low attitude UAV system combining with the use of powerful automatic photogrammetric processing software. The system makes it fast and flexible to get the high resolution digital and optical image. It can support the application of large-scale mapping.



Figure15. the orthophoto imagery of Niede in Guangzhou city

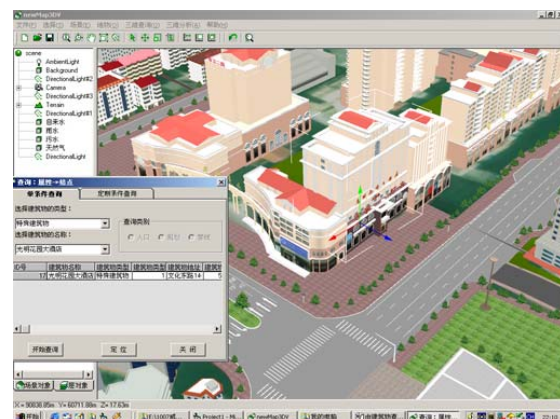


Figure16. a 3 dimension scene of Weihai city

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