TWICE-IMAGING AIRBORNE CAMERA SYSTEM WITH DISTRIBUTED SENSORS

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ABSTRACT:

Digital airborne cameras play a significant role for aerial Photogrammetry development from analog to full-digital age. Because of the gap between digital sensor performance and Photogrammetry request, digital airborne also becomes the bottleneck of full-digital approach. In this paper, we present a design of twice-imaging airborne camera system with distributed sensors based on film camera, and carry out optical experiments to obtain practical images, MTF (Modulation Transfer Function) and the scattering light traced by ZEMAX software.

1. INTRODUCTION

Aerial Photogrammetry is developed from analog to full-digital age. Digital Airborne cameras play a significant role to break the bottleneck of full-digital approach partly. In this paper, the status and performance of film and digital airborne camera systems have been discussed and compared firstly. Then a novel design of twice-imaging digital airborne camera system with distributed sensors is presented. To prove the design feasibility, twice-imaging optical experiments and measurement have been carried out.

2. DIGITAL AIRBORNE CAMERA DEVELOPMENTS

Since 1980s, several film airborne cameras have emerged in the world. The most representative ones are RC20 and RC30 by Leica Corporation in Swiss, LMK2000 and RMK TOP by Zeise Corporation in German and LFC by Hek Corporation in USA. Especially, RC30 represents the highest level in film airborne camera systems.

As a new milestone in Airborne Photography, digital airborne camera makes digital images by CCD (charge coupled device) sensors instead of film ones. At present, there are several off-the-shelf of digital airborne cameras, such as UltraCamD (UCD) Airborne camera by VEXCEL Corporation, DMC by Z/I Imaging Corporation and ADS40 by Leica Corporation, in which UltraCamD and DMC employ area-array CCD sensors, but ADS40 employs linear CCD sensor, refer to Fig.1. In China, digital airborne camera development is just in the starting stage. Here SWDC Airborne camera is the first practical one. In the Airborne remote sensing and photography, UCD, DMC, ADS40 and SWDC are the most familiar cameras in China.

The UCD Airborne camera uses parallel sensors with a set of 8 optical cones to assemble 13 area array CCD into a large format digital image in natural color, false color and infrared band here. UCD has in-flight control functions, including images quick-view, online exposure control and so on.

UCD DMC

ADS40 SWDC

Figure 1. Several airborne cameras

The DMC camera, in the gyro stabilized platform, has many similarities with film airborne camera (for example RMK-TOP). The camera consists of an optical system to slip into the platform bore. The frame can take up to 8 camera modules: 4 high resolution panchromatic CCD ones and 4 multispectral channels with reduced resolution. Special efforts have been invested on rigid mounting technology for the individual camera heads in order to ensure precise alignment of the optical axes to each other.

The ADS40, as a "pushbroom" camera, creates high multispectral resolution and stereo panchromatic imagery with "three line scanner" principle. The sensor contains seven linear CCD imaging chips arranged on a focal plate, four of them are

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fitted with interference filters to determine the spectral bandwidth of the channel, Blue, Green, Red and near infrared, and three of them are panchromatic on the focal plate to receive light from the forward, nadir or backward direction.

The SWCD-4 camera uses 4 area array CCD imaging chips for all panchromatic channels. With the certain overlapping of the 4 CCD, the images can be mosaic to be large format imagery.

Full digital image process avoids the hassle of film rolls and costly film storage, while facilitating access to imagery. According to the different imaging conformation manners, digital airborne cameras can be classified into two kinds:

1. Multi-CCD's central projection manner. Because the CCD format is small, single CCD can not satisfy practical photography request. So, all of UCD, DMC and SWDC-4 adapt multi-CCD chips and central projection manner. But this kind of central projection in multi-CCD case will never be rigid but loosen.
2. Linear CCD "pushbroom" manner. As for linear CCD imaging, the exposure is controlled by varying the integration time. Since there is no shutter, the sensor records data continuously from the beginning to the end of a flight line. For the linear CCD data processing, the inertial navigation must be required and equipped in the ADS40. The known interior and exterior orientations are used to reinforce the geometric constraints and restrict the search space at known locations along the flight line. This rigorous measurement is completely different with the conventional Photogrammetric procedure which can not be fit linear CCD image processing.

Both of the two imaging conformation manners have their specialties. Concerning for the area-array CCD higher quality pixels and more compatible with current workflows than linear CCD, we mainly focus on area-array CCD based airborne cameras.

Most digital airborne cameras use multi-area-array CCD imaging system, which causes loosen central projection imagery conformation and lower base-height ratio. All the problems affect the geometry accuratcy. While the conventional film airborne cameras have come to mature, which have rigid central projection for images, high ratio of baseline and flight height, well defined epipolar geometry and collinear equation theory. Based on film airborne camera's gyro stabilized platform in this paper, a digital airborne camera with twice-imaging scheme has been applied. This new kind of digital airborne camera can realize the same image format, baseline-height ratio, and rigid central projection imaging as that of film airborne camera.

3. TWICE-IMAGING CONFORMATION SCHEME

All civilian camera and airborne film cameras use once-imaging scheme, in which images are captured on the imaging plane of optical system. Multi-CCD Airborne camera also use the once-imaging scheme, which brings us a lot of problems such as loose central projection, low baseline-height ratio, and complicated image processes. All the problems will cause system errors are inevitable. Twice-imaging scheme in Fig.2 can solve the above problems.

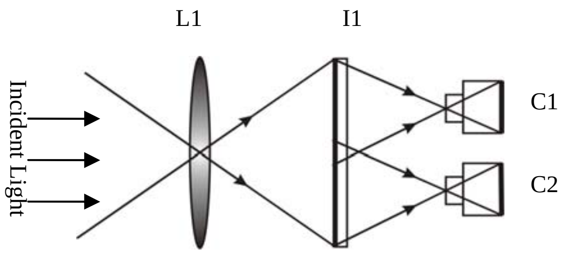

Figure 2. Twice-imaging conformation

The whole process of twice-imaging conformation is composed of two procedures. The incident light makes images on the imaging plate of intercepting optical component I1 through lens L1 firstly; the light on I1 scatters to the distributed CCD sensors, C1 and C2, by which CCD sensors output the digital images secondly. Twice-imaging scheme has several advantages:

1. The digital image format is no longer limited by the digital sensor area instead of the intercepting optical component. So, it provides us a method to enlarge the digital image area.
2. The image on the intercepting optical component is fit to the rigid central projection of the Lens L1. So, there is no loosening projection error.

4. DISTRIBUTED DIGITAL IMAGING SENSOR

Distributed imaging sensors have been successfully used in target recognizing, tracing and monitoring, 3-D object reconstructing and so on. Distributed sensors play an important role in twice-imaging resolution. In this paper, we take four distributed CCD sensors as an example, refer to Fig.3. The distributed CCD sensors system is composed of master control unit, CCD photo-sensitive unit, data management unit and other peripherals. This distributed sensor is designed to offer exposure speed at one frame per second, which is benefit from the parallel CCD storage architecture. The master control unit is developed from MCU (Micro Control Unit) system. FTF4052 CCD chips produced by DALSA Corporation are used in the distributed CCD photo-sensitive units. The data storage management units, with FPGA (Field Programmable Gate Array) approach, can be used to transfer image data to hard disk with ATA5 protocol.

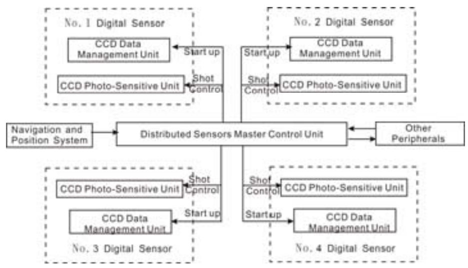

Figure 3. Four distributed CCD imaging sensors

5. TWICE-IMAGING AIRBORNE CAMERA SYSTEM INTEGRATION

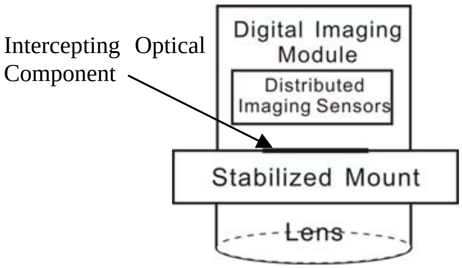

Figure 4. Film camera based twice-imaging airborne camera

The stabilized platform and lens of traditional film camera are still high qualified for application. Based on them, the film cassette can be replaced by a particular digital module with distributed CCD digital sensors, an intercepting optical device and some other equipment. And then, the film airborne camera is changed into be a digital one. The construction of twice-imaging airborne camera is shown in Fig.4.

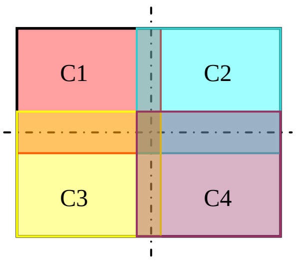

Figure 5. Four distributed CCD sensors imaging format

Twice-imaging scheme is the critical technology in this airborne camera. An intercepting optical component is used to realize twice-imaging scheme in the optical system. Each of the digital images has vertical and horizontal overlap with the adjacent images; refer to C1, C2, C3 and C4 in Fig.5. All the digital images can mosaic to an intact large-format one through a series of processes, including light dodging, geometric correction and so on. Due to the relative position between distributed cameras and intercepting plate fixed, so the exterior orientations of them are almost constant. And also, the primary optical axes of distributed cameras are vertical to the intercepting plate, which is benefit to image processing.

6. OPTICAL EXPERIMENTS AND SIMULATION

For proving the feasibility, twice-imaging optical experiments have been carried out, and high resolution digital images of ISO12233 were obtained. With ISO12233 resolution testing card, two kinds of granularity ground glasses and Nikon D200 digital cameras are used in the experiments. According to MTF measurement of the intercepting optical devices, the limiting spatial frequency is larger than 100lp/mm. And the MTF is better than 0.5 under the spatial frequency is 50lp/mm.

The forward and backward scattering of the ground glass' frosting side is simulated by ZEMAX, which can explain the grounded glass function in twice-imaging scheme. In Fig.8, the parallel light scattering of intercepting optical component with the parameters (see Tab.1) is shown. By changing and optimizing the Parameters in the simulation, the MTF will become better. Seemly, grain density, size and curvature of ground glass are the main parameters for the twice imaging quality.

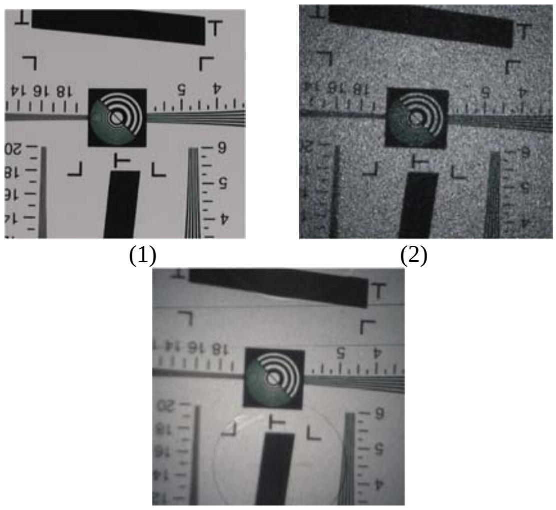

Figure 6. (1) ISO12233 original image, (2) and (3) are intercepting images on different granularity

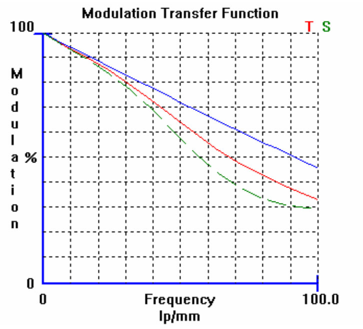

Figure 7. MTF measurement of the intercepting optical plate

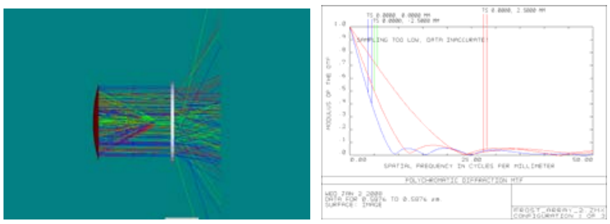

Figure 8. Scattering light tracing of the intercepting optical device

Parameters	Num	Unit
Diameter of Plate	72	mm
Grain density	518400	
Grain size	0.1	mm
ground glass curvature	2	mm

Table 1. Intercepting optical device parameters

7. CONCLUSIONS

Digital airborne cameras are taken as a new milestone in Airborne Photography. For practical demand of airborne remote sensing and photography, novel optical design and digital imaging system are needed greatly. Twice-imaging and distributed sensors can be a feasible solution for new kind of digital airborne camera development.

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