4 Aerial Cameras

INTRODUCTION

The acquisition of good-quality imagery is central to the accuracy of photogrammetric mapping. Three issues impact on image quality: camera lens, photographic film, and optimum exposure of the film along with the subsequent processing [Mark, et al, 1983].

AERIAL CAMERA

The aerial camera is an important and critical part of the photogrammetric process. The camera records the existence of phenomena at an instant in time. For precision mapping, it is important that a number of requirements be met [Bormann, 1969]. The aerial camera should:

- be of high optical lens quality to ensure that imagery is discernable,
- be capable of performing under extreme conditions found in the aircraft, such as temperature and humidity,
- be simple to use during the photo mission,
- be equipped with safeguards to protect against operator blunders during the operation,
- be as automatic as possible,
- be able to preserve the elements of interior orientation so as to preserve the internal geometric relationships existing within the camera, and
- be able to take a series of exposures or single photos with an instantaneous release of the shutter.

A new demand being placed on the camera is the integration of positioning the location of the exposure station using the global positioning system (GPS) and the integration of inertial measuring units to the photogrammetric process.

The design of aerial cameras has significantly increased their accuracy and performance. Improvements in lens design has been influenced by better manufacture of the lens elements, advances in applying the anti-reflective coatings and advanced computer programs that optimize the design of the lenses [Farrow, 1986]. Coupled with these items are better construction practices and quality control procedures like testing.

Modern lenses are practically free of any lens distortion. It is now possible to find distortion values at the 1µm to 2µm level or lower. In addition, the enhanced design has lead to improvements in the resolution characteristics. Tests show that corner values of up to 40 lp mm^{-1} for a standard 230mm x 230mm format camera are possible. Finally, many of the camera lenses have extended their spectral ranges to the infrared region thereby making the camera more universal in that both panchromatic and infrared film can be used with the same camera system [Farrow, 1986].

A further development that has contributed to improved imagery is forward motion compensation (FMC). This feature advances the film during the exposure to compensate for the forward motion of the aircraft during the exposure. This is done by progressing the film-feed in the magazine. Theoretically, the detail will be corrected for but this is only valid for truly vertical photography over flat terrain. Image blurring will still occur due to [Farrow, 1986]:

- Geometric problems caused by the camera not being truly vertical,
- Residual vibrations that exist with camera mounting, and
- Lateral movement of the aircraft due to pitch and roll.

Different manufacturers accommodate fiducial mark imagery in diverse manners with FMC [Farrow, 1986]. Zeiss Jena, as an example, captures an image of the fiducials at the midpoint of the exposure cycle. Zeiss Oberkochan, on the other hand, exposes the fiducial during the whole exposure resulting in an elliptical image. The minor axis of this image is 100mm while the major axis is approximately 125mm.

While photogrammetrists have used imagery for years without FMC capabilities, the compensation of forward motion has important economic advantages. First, because the image is clearer, it should be possible to use smaller scale mapping, provided that the aerial film can resolve the detail that needs to be imaged on the film. Smaller scale, particularly for larger projects, saves money in the mapping. Even if the same scale is used for mapping, there are still economic advantages of FMC, most notably in the reduction of revising detail on the map that were hard to identify on the imagery [Mark et al, 1983].

STABILITY OF AERIAL CAMERA

Because of the large capital investment required for purchasing an aerial camera, it would be beneficial to see if the interior orientation parameters change over time. Hakkarainen [1984] reported on tests performed by the ISPRS WG I/2[1]. The results are listed as follows:

- The calibrated focal length (CFL) remained stable over time. Changes at the micrometer level were noticed but these were about the same as the standard deviation from the calibration of the CFL.
- The fiducial marks were found to be very stable.
- The mean radial lend distortion was also found to be stable. Moreover, camera age did not appear to be a factor.
- Changes in decentering distortion were noticed but their effect in a photogrammetric solution was deemed to be insignificant. The asymmetric distortions can be caused by decentering distortion within the individual lens elements, tension between the lens elements and camera cone, and some small residual effects from not having the focal plane perpendicular to the optical axis.
- It was found that dismounting the camera or service did affect the CFL by over 15 µm.

The recommendations for calibrations from

[1] International Society for Photogrammetry and Remote Sensing (ISPRS) Working Group I/2.

this working group are:

a. After each accident or service, calibrate the camera.
b. For normal photogrammetric applications, a three-year calibration period is acceptable.

DIGITAL AERIAL CAMERAS

A new trend in aerial cameras for photogrammetry is the development of digital cameras. These are really not new since digital imagery has been used for mapping for years. What is new is the development of cameras that claim to have the geometric accuracy comparable to existing film-based cameras. One significant problem remains. It is not technically feasible at this time to have one single area array that covers the entire 23 x 23 cm format of conventional aerial cameras. Thus, the two main mapping camera manufacturers have approached the problems in two distinctly different manners. Leica Geosystems use a linear array while Z/I-Imaging has looked at using a package of area arrays to form the image.

Z/I-Imaging has introduced the Digital Modular Camera (DMC) system. What is unique about this system is the use of one to eight CCD area camera modules that can be mounted together in different configurations. This enables the user to acquire up to four high resolution panchromatic images with the capability of adding up to four multispectral images with reduced resolution. All CCD cameras are mounted inside the optics frame. Since the DMC camera is the same size as the RMK-TOP analog camera, it will fit into the Zeiss gyro-stabilized platform. A schematic diagram of the component parts of the DMC are shown in figure 1. Normally, airborne GPS is integrated with the DMC system. Additionally, the flight management system (FMS) is used to operate the camera system. Finally, an inertial measurement system can be installed in the camera frame [Hinz et al, 2001].

The electronics module provides the control for the DMC system. It controls the camera module. Not only does it operate the camera shutters and collect the digital imagery, it also communicates with the control unit. The control unit is the heart of the electronics system. It provides the communications with the external components to the camera system, monitors data flow and sends the captured imagery to the data storage RAID [Hinz et al, 2001].

CAMERA CALIBRATION

There are several different methods used in the calibration of aerial cameras. They can be divided into two main categories: component and system. The component category can be divided into three different methods of calibration: laboratory, field, and stellar calibration.

The system concept is unique in that it looks at the whole process. For example, if a client wanted to obtain a digital terrain model (DTM) over an area by photogrammetric means, the system approach looks at the entire process. In this example those phases of the project that would be evaluated include defining the project scope of work, project planning, acquisition of ground control and imagery, processing the imagery, measurements on the imagery, and post-processing of

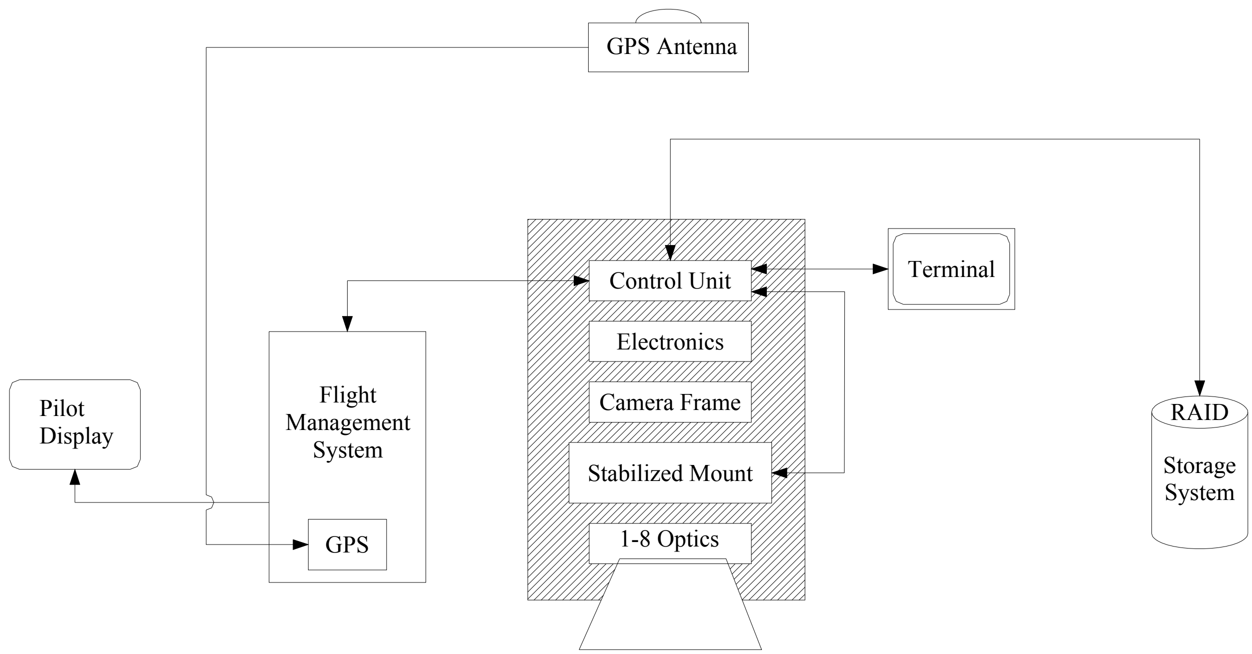

Figure 1. DMC system [adopted from Hinz et al, 2001].

measurements into the final deliverable to the client. As one can see, the system approach involves the integration of a myriad of steps involved in the creation of the final product.

Merchant [1982] shows how photogrammetric system calibration stems from Eisenhart's conceptualization. As Merchant points out, Eisenhardt's model involved the establishment of two sequential phases

"- the total operational measurement system is first defined in terms of equipment and operations, each with allowable ranges. The result is the 'specification' defining the measurement system.
- After the measurement system has been defined by specifications, it is exercised repeatedly and results of its measurements are compared to a standard of higher accuracy."

Merchant, 1982, p.179

What this means is that specifications are defined for each part of the process. This forms the benchmark upon which subsequent measurements will be made.

FILM

As digital imagery becomes more prevalent within the photogrammetric industry, professionals are taking a harder look at the quality of the imagery. Film has a very unique property of high geometric accuracy. This is due to the small grain size used to capture the image, generally in the range of tenths of a micrometer [Diehl, 1992]. On the other hand, the radiometric quality is very poor on a grain-by-grain analysis because an individual grain can only be black or white. No intermediate preys are possible.

A scanned image has much different characteristics. Because the pixel is larger than the grain in a film, usually 10 μm or larger, the geometric quality of the image is poorer. Yet, the radiometric quality is much better because each cell can have different levels of gray values, from white to black. When converting data, there is always a loss of quality. When scanning a photograph, the grain structure within the film is the main contributor to the radiometric noise of the digital image. This is more pronounced with smaller pixels [Diehl, 1992].

Film density (D) is defined as a logarithmic ratio of the transmitted to incident light. For example, a value of D = 1.0 means that 10% of the incident light passes through the film [Diehl, 1992]. Granularity is measured as the root mean square (RMS) error of the density. The ISO standard defines the standard deviation (σ_D) of an uniformly exposed film at D=1.0. The film is exposed with a 50 μm round aperture and the value multiplied by 1,000 and rounded to obtain an integer value. For reconnaissance film, a typical range of granularity is 8-35.

REFERENCES

Diehl, H., 1992. "Optimal Digitization Steps for Usual Film Materials", International Archives of Photogrammetry and Remote Sensing, 29(B1):1-6.

Farrow, J.E., 1986. "Aerial Survey Camera Trials", Photogrammetric Record, 12(68):167-174.

Hinz, A., C. Dörstel and H. Heier, 2001. "DMC – The Digital Sensor Technology of Z/I-Imaging", Photogrammetric Week 2001, Heidelberg, pp 93-103, available at http://www.ziimaging.de/news/otherdocs/hinz.pdf.

Mark, R-P, G. Voss, and U. Zeth, 1983. "Some Aspects of Forward Motion Compensation in an Aerial Camera", Technical Papers of the 49th Annual Meeting of ASP, Washington, D.C., March 13-18, pp 534-544.

Merchant, D., 1982. "Photogrammetric System Calibration", Technical Papers of the 48th Annual Meeting of ASP, March 14-20, pp 178-181.