THE ALL DIGITAL PHOTOGRAMMETRIC WORKFLOW: REDUNDANCY AND ROBUSTNESS

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Commission I, WG I/6

KEY WORDS: Digital Camera, Quality Assessment, Analog Film

ABSTRACT:

Digital aerial cameras, among them the UltraCam D, the new large-format digital aerial camera of Vexcel Imaging, are ready to replace the aerial film camera. This is reason enough to highlight the improvements in radiometric and geometric quality that such a camera provides. Is it the ability to resolve dark shadows, is it the ability to simultaneously register panchromatic, true color and false color infrared or is it the ability to increase the forward overlap at no extra costs for film, development and scanning, we are convinced, that with such digital cameras, a novel strategy of source image acquisition can be considered.

Aerial photogrammetry has long used a convention of 60% forward overlap and 20% sidelap, in order to provide for stereo compilation and the generation of products such as digital terrain models (DTM) and orthophotos.We argue that digital cameras can be used to challenge standard photogrammetric conventions: no longer is film grain an issue, high radiometric resolution at a 12 bit level and no longer is the number of images the predominant driver in defining a photogrammetric project. Increased redundancy and higher overlaps provide a key to optimized levels of accuracy, automation and robustness in a production environment.

The design of the UltraCamD with its parallel architecture permits a very high framing rate, thus affording flexibility to select a forward overlap of up to 90%. Further, the role of parallel architecture in sensor design, together with efficient data transfer and storage options, is discussed. If this change in the strategy of image acquisition take place, an enhancement of automation and robustness in the photogrammetric production can be expected.

1. INTRODUCTION

The replacement of the aerial film camera obviously started in July 2000 with the product announcements of the ADS-40 by LH-Systems (now Leica Geosystems) and of the DMC by Z/I Imaging. In May 2003 the UltraCamD was introduced. This is a 90 Mpixel large format aerial camera by Vexcel Imaging with a focus on a one-on-one replacement of aerial film cameras. This is achieved by the use of an unchanged work flow, based on the well known frame image.

The initial economic advantages can obviously be detected in the smooth all-digital operation and in the reduction of expenses when costs for film, film development and scanning can be ignored.

Beyond these initial advantages the all digital photogrammetric workflow offers numerous opportunities for improving the current state-of-affairs of photogrammetry as much so that one could speak about a "paradigm shift". The most important opportunity is the ability to dramatically increase the forward overlaps in photogrammetric surveys without any added cost, and producing a much higher level of automation in photogrammetric data analysis. Photogrammetric software will have to be adjusted to go from current stereo, thus "2-ray photogrammetry" towards "multi-ray" solutions.

Beside this "multy-ray" concept the ability of such digital aerial camera to simultaneously register panchromatic light at high geometric resolution, true color red-green-blue and false color infrared light offers new opportunities in photogrammetric color sensing.

2. THE ULTRACAM$_D$ DIGITAL CAMERA

2.1 DESIGN ISSUES

The sensor unit of Vexcel's UltraCamD consists of eight independent cameras, so-called cones. Four of them create the large format panchromatic image at a size of 11500 by 7500 pixels. The other four cones are responsible for the multi spectral channels of the UltraCamD, i.e. red, green blue and near infrared (Figure 1).

The panchromatic part of the camera combines a set of 9 medium format CCD sensors into a large format panchromatic image. The multispectral channels are supported by four additional CCD sensors.

Fig. 1: UltraCamD Sensor Unit and Storage/Computing Unit

Each of these 13 CCD sensors is the front end of a separate imaging module. It consists of the sensor, the sensor electronics, a high end analog/digital converter (ADC), a fast digital signal processor (DSP) and the IEEE 1394 data transfer unit.
The raw image data is transferred via the IEEE 1394 interface to a separate storage module of the Storage and computing Unit of UltraCamD.
Thus the camera offers a frame rate of more than 1 frame per second, exploiting the benefit of its parallel system architecture.
The panchromatic image consists of 11500 pixels cross track and 7500 pixels long track. Color is simultaneously recorded at a frame size of 4k by 2.7 k pixels for red, green, blue and near infrared [Leberl 2003].
The Storage and Computing Unit (SCU) of UltraCamD is responsible for the raw image data storage. It offers an entire storage capacity of 2 * 780 GByte, i.e. space for 2692 images stored twice on two separate sets of HDDs.
The system architecture shows again a highly parallel concept, each CCD unit of the camera head (Sensor Unit) has its own "private" storage unit, including a small scale computer and a set of two mirrored and sealed HHDs.
In addition to the storage capacity the SCU offers calculating power for the postprocessing by exploiting its 15 processor units.

3. FROM 60% TO 90 % FORWARD OVERLAP

The traditional photogrammetric workflow is based on 60% forward overlaps. Stereo operations strictly employ 2 intersecting projection rays, ignoring the lack of sufficient redundancy. With the advent of digital sensors, the number of images is no longer a factor of the project costs, as long as processing is automated. This encourages thinking about the use of higher than 60% forward overlaps (Fig. 2).

The benefit of such novel strategy is manifold. Most important is the fact, that each position on the ground is mapped 5 times at an overlap of 80 % and 10 times at an overlap of 90 % vs. the 2.5 times appearance of a terrain position at 60% overlap.

UltraCam is able to collect up to 2700 images per mission at a frame rate of up to one frame/second and therefore supports routine use of 80% forward overlaps in almost all circumstances. Smaller urban mapping projects might benefit from the use of even 90% forward overlaps. The aero-triangulation will become more robust since mismatches of tiepoints will disappear. DEMs will also be without mismatches and all terrain segments will have coverage. An integrated system with geo-positioning tools and multi-ray photogrammetric processing will result in a *DEM-robot* and will also produce true orthophotos robotically.

The high overlap can be produced by increasing the frame rate during the photo mission. Taking into consideration an aircraft speed of 75 m/sec and a frame rate of one frame/second a minimum base length of 75 m can be obtained. In the case of a 7500 pixel image dimension along track the 60 % overlap causes a base of 3000 pixels, thus a minimum GSD of 25 mm (50 mm at 80% overlap and 100 mm at 90 % overlap) can be achieved.

Additional flight lines to improve the side overlap from 30 % to 60 % can be considered for dense built up areas, but will cause additional costs. In dense built up areas such flight concept is then able to avoid nearly any occlusion and therefore offer a optimal dataset for true ortho production.

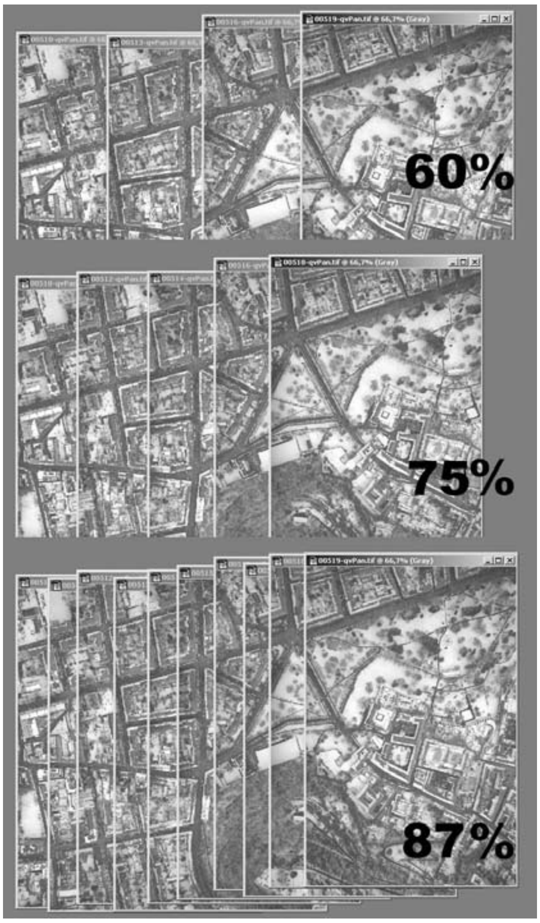

Fig. 2: Sample of a flight line with 60% (top), 75 % (center) and 87 % forward overlap (bottom). This corresponds to a relative base length of 40%, 25% and 13% of the image dimension. The number of frames doubles between each of these examples.

4. DIGITAL VS. FILM SENSING

The digital sensors have advantages over film due to the absence of grain noise, due to the dynamic range at 12 bits per pixel as opposed to <8 bits in film, and due to an inherent geometric stability because of the absence of moving elements and of photo laboratory processes.

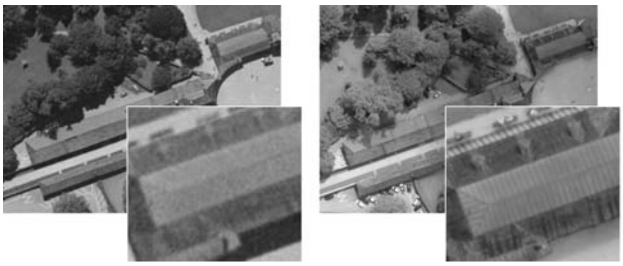

Figure 3: Comparing aerial film and digital image. Left is scanned film at a pixel size of 15 µm (GSD of 15 cm); at right is the digital image with a GSD=17cm (from Leberl & Gruber, 2003).

The absence of grain in the digital image and the high radiometric performance e.g. at shadow areas offers the ability of dense and reliable automatic DEM data extraction.

5. MULTISPECTRAL SENSING

One important benefit of some digital cameras is the multispectral capability. UltraCamD offers such simultaneously sensing of high resolution panchromatic information and additional multispectral –thus red, green, blue and near infrared (NIR)- information. The method to combine panchromatic and multispectral subimages is known as the “pansharpen” method. The output image of such sensor can then be a high resolution true color image or a high resolution false color infrared image. The benefit of the multispectral sensing is obviously the simultaneous recording of all bands, i.e. any classification can be performed without cumbersome registration of different scenes. Additional ideas about photogrammetric color sensing may be found in [Leberl et al., 2002].

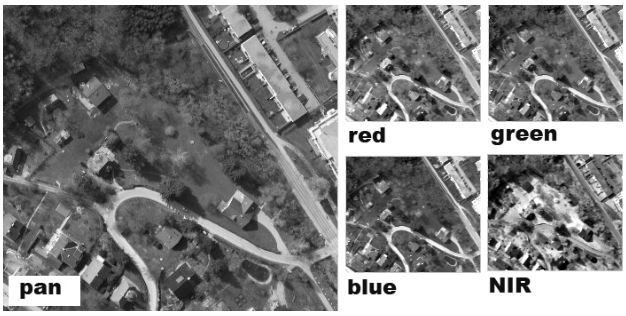

Fig. 4) Panchromatic high resolution image (left) and four multispectral channels (right) built the source data set of UltraCamD.

6. WORKFLOW ISSUES

The remaining analog gap of the end-to-end photogrammetric workflow has been closed by the digital large format aerial camera.

This leads to a new way of data handling, archiving and data retrival. No longer manual interaction with cut film sheets or uncut rolls of film but computer controlled digital archives will help to manage huge amounts of digital data.

The digital images from digital aerial cameras need to fit into such archiving systems but also into the traditional workflow of the existing photogrammetric production.

By principle, the UltraCam-D data flow will dovetail with an existing softcopy photogrammetric operation. The modular setup of the UltraCam-D approach supports a flexible connection with a customer’s preferred data management arrangements. There are four levels of image data:

Level 00 Raw image segments read out from each CCD, redundancy by mirroring
Level_0 Verified image segments, no redundant storage
Level_1 Image segments radiometrically corrected and rearranged for efficient stitching
Level_2 Stitched (i.e. geometrically and radiometrically clean), color held separately
Level_3 Final color (false color IR) pansharpened image product

Raw level-00 aerial digital photography gets collected on board the survey plane onto the disk and CPU arrangement (the SCU). A storage volume of 1.5 Tbyte is available with the basic UltraCam-D configuration. Half of the storage is for the collected image segments, the other half is used to mirror each image onto a duplicate set of disks. Upon completion of a flight mission and some preprocessing into level 0 or level 2 on board the survey plane, the images are being transferred from the on-board SCU onto a mobile storage unit (MSU). This consists simply of a set of 14 HDDs and has the ability to receive an entire set of Level 0 image data from the SCU within about 1 hour.

The SCU is itself also “mobile” and can be moved from the plane to optionally perform the function of a “ground processing system”. Transfer of the digital data to the home office is via the MSU.

The camera system will be ready to fly on a daily basis, since processing the collected data and transferring them off the plane can be achieved sufficiently quickly for a survey flight to resume the next day.

7. CONCLUSIONS

The large format digital aerial camera will clearly close the last remaining analog gap of the all digital photogrammetric workflow. This is reason to figure out the novel abilities of such new source data production.

We have focused on four major advantages of the digital system, 1) the ability to produce a higher overlap, up to 90 % along track, without additional expenses for film, 2) the absence of grain noise and therefore a much higher quality in DTM production, 3) the ability of simultaneously multispectral sensing and 4) the all digital workflow with its inherent benefits.

These and other specific advantages of the digital camera may be reason enough to foresee a fruitful impact of this new instrument, or, more enthusiastic, foresee a remarkable change of the photogrammetric landscape, combining enhanced productivity, higher degree of automation and more robustness.

8. REFERENCES

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