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DMC - The Most Versatile Digital Large Format Camera in the Market

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1. INTRODUCTION

Over the past 10 years dramatic changes have occurred in the commercial earth imaging market. Not only the successful introduction of aerial large format cameras during the last 3 years, but also the availability of hyper spectral and high resolution remote sensing data, *LiDAR* (*Li*ght *D*etection *A*nd *R*anging) or radar systems have revolutionized this market. The need for collection, compilation, distribution and presentation of information about our world however is still growing and more interestingly does stop at a certain accuracy or coverage level.

From a completely rational point of view the whole earth should be covered by a very dense raster where each raster element is represented by several layers storing “visual information”, “height information” and “spectral information” as well as “descriptive information”. Having such gridded, georeferenced information available in data bases, derivatives such as land use assessment, fly through or various planning and engineering work can be featured. The big question however is, who will manage and build such data bases and what are the requirements for sensing systems to populate them?

This paper describes how the growing demand for earth imaging information can be covered by the Z/I Imaging Digital Mapping Camera (DMC) and discusses aspects of versatility for aerial camera systems.

2. DMC CONCEPT

In general, the DMC adds digital capabilities to the existing image capturing technology. As direct digital airborne camera systems are complex systems, the DMC is more than the simple exchange of film for silicon. Several additional issues such as data transfer rate, image post-processing, color fusion, calibration, image archiving, and image data management have also to be addressed. The DMC system concept, introduced by Hinz, Heier and Dörstel (Hinz 2001, Heier 2002), is based on matrix sensor technology and thus the DMC provides very high radiometric and geometric stability (Madani 2004, Dörstel 2003).

The DMC camera system has been productive and field-tested since 2003 at more than 20 sites all over the world. The modular system design makes it easy to maintain and, more importantly, the system can easily keep up to date with technological changes. Besides its ease of use, the main advantages of the DMC system are:

- Economy of use
- Wide operating range
- Fully automated workflow
- Availability of multi spectral information

As these are very important factors for today's camera users this paper will discuss these aspects in more detail.

2.1. Economy

Economical usage of a system is one of the key factors and this certainly means more than just the overall system purchase price. Economy of a system has multiple aspects. Besides the vendor's capability to adapt to changes in technology, the overall production chain must be considered and assessed, as should the costs of ownership.

First of all DMC, was designed to be a modular camera. The modular design concept means that during development a considerable effort was spent to make sure that components which are expected to have fast innovation cycles are easy to exchange. A very good example is disk drives. New high capacity disks can be replaced and directly contribute to more efficient use. The modular concept permits new technologies to be integrated easily, as the component-based construction supports different upgrade paths for individual components and actually helps to save the investment. Even security aspects for the air crew have been addressed. DMC is fully compliant with the American DO 160D and the ISO 7137 regulations and as such is designed to be a very robust and reliable system for use in aircraft. All parts and components have been selected with special care to operate in the rough conditions typically faced in aircraft.

Second, performance counts. With a field of view of 69.3° the DMC system is directly comparable to the efficiency of the well known RMK-Top 15, and this cost advantage directly influences the total cost of ownership. Looking at the number of images in a strip, we can say that this number is of nearly no importance in the totally digital workflow, as the costs for film material and development are no longer a consideration. On the other hand, the number of strips is still significant. The DMC offers the widest field of view of all large format cameras and hence offers the best performance. In general the flying costs can be assumed stable if the same number of strips is required.

In order to improve the reliability of data acquisition, real time capability is demanded. Technology to support crew decisions while still in the air over the project site removes any uncertainty over data completeness prior to landing. The DMC system includes a real time video camera to automate and support photoflight navigation. From this camera, thumbnails are captured with each exposure featuring real time project status and overview. The camera operator can check for ground coverage, clouds and if applicable for correct exposure settings right in the air. This is one of the most important advantages digital camera technology offers to the air crew. A trained operator can assess the quality of the images taken based on histogram inspection or image assessment and hence reduce the need to revisit the mission area.

The DMC system is a total solution, designed to fit perfectly to individual customers requirements. As a complete Flight System, which includes mission planning, sensor control, post processing and data management, the DMC is a real production tool. Looking at total costs of ownership and availability, service aspects also need to be investigated. As final results depend on proper functioning of all components involved, the availability of service from a single vendor, who can support the entire system, may have an important impact on aircraft down-time is grounded in the event that service is needed.

Moreover, the new DMC Flight Data Storage (FDS) system guarantees highest possible data security due to its special thermal- and shock absorbing design. Easy handling and the flexibility to distribute the load within the aircraft makes it possible to mount the DMC camera system inside a single engine aircraft and thus helps to reduce the total costs of ownership. While a less capable, no-frills system may reduce the upfront cost, it is reliability in the typical operating environment that makes a system cost efficient.

2.2. Operating Range

The camera was designed to perform under various light conditions with a wide range of exposure times. Features such as electronic Forward Motion Compensation (FMC) and 12-bit per pixel radiometric resolution for each of the panchromatic and color channel camera sensors provide the capabilities of operating even under less than favorable flight conditions. The DMC can produce small-scale or large-scale (1:4000 – 1:30.000) images with ground resolutions ranging from less than five up to 80 centimeters. The results are images with greatly improved radiometric resolution and increased accuracy of photogrammetric measurements

There are a lot of discussions whether forward motion compensation (FMC) is needed for digital sensors or not. Let’s look at this question from a technical standpoint and let us assume a stabilized mount is in use, so that image blur comes only from uncompensated camera “movements”.

Forward motion compensation is a technique introduced for analogue cameras to minimize blurring in aerial images. The reason of the blurring effect is that while the image is being exposed, the aircraft moves and as a result the projection of an object point into the photo is shifted. The FMC technique compensates for that effect by shifting the image opposite to the flight direction to keep the position of the projected object points fixed during exposure time. This technique is well accepted in the photogrammetric world and (together with use of stabilized platforms) has helped to deliver sharp images. For digital sensors, there are at least three possible approaches to compensate forward motion:

- Implement Time Delayed Integration (TDI)
- Implement mechanical FMC for a whole CCD array
- Adapt read out time so that forward motion effects are negligible

Time Delayed Integration is the technique the DMC camera has realized. The principle is to shift the image electronically over the CCD. Practically that means that the CCD is read out while the exposure takes place.

Mechanical FMC is realized in the DIMAC camera through use of a CCD which can be shifted by Piezo elements.

Adaptation of read out time is realized by line scanners. Here the effect of forward motion is assumed to be negligible because of the very short read out cycles but this also results in very short integration times.

So effectively we can divide all commercial camera systems into two groups: cameras which implement FMC and cameras with no FMC technique. Practice has proven that both approaches deliver acceptable results. However the question is, “What do I have to give up?”.

Image Motion is a function of speed, height above ground, exposure time and the required spatial resolution. The faster my camera platform moves, the shorter must be the exposure time to avoid blurring and the lower I fly, the faster my object point moves across the focal plane. The resulting

image quality is determined by spatial and radiometric resolution as well as by the quality of the optical system.
The sensitivity of a CCD element however is a function of exposure time and pixel size. The larger the pixel element, the more photons can be collected in a certain time interval and the better is the resulting image quality. The problem with a smaller pixel size is that an object moves faster out of the pixel element. This clearly shows a limit for non-FMC sensors, as no additional integration can be performed in subsequent pixel elements. One may argue that the aircraft can reduce speed over ground, and that's correct until it comes to the minimum speed at current load. So we can say, to capture high quality images we have to resolve the optimization problem of minimum speed of an aircraft, required ground resolution or corresponding flying height, and the fact that marginal weather conditions require longer exposure times. These are general limitations coming from the physical characteristics of the components in use and we can conclude as follows. Systems offering FMC can be used in a broader operation range because some of the limitations, such as speed over ground or long exposure times, are compensated by FMC.
To summarize, systems, like DMC, which have realized FMC are better suited if it comes to high resolution, operation under marginal weather conditions and/or higher speed at low altitudes. Additionally, even with shorter exposure times, the larger the pixel element of the sensor is, the better the image quality (for example more details in shadows) that can be reached. Systems without FMC are limited in their operation range as short integration times limit usage to good weather conditions.

2.3. Workflow

In regard to the practicality and economy of the production workflow, considerations include the efficient processing, management and distribution of the image data. Will your operators need special training to cope with the data? Does your system support output of standard imagery which can be used in any standard softcopy system? DMC images can be processed with all existing photogrammetric workstation without any modification or software upgrade and the data are useable in any standard softcopy system on the market.

Further benefits of using the integrated DMC technology (hardware, firmware, and processing software) as an aerial photogrammetric solution are the completely digital workflow, which eliminates the process of scanning and film processing. This saves a considerable amount of time. In addition, post-processing of the digital imagery is very fast; a typical flight project can be processed in a few hours, especially having the new DMC Distributed Processing system (Dörstel, 2005) in use, where processing of 2000 images can be reduced to less than 24 hrs.

2.4. Multispectral

Another important improvement is that today's digital cameras can capture multiple spectral bands in a single flight. This "Fly once, get many …" idea has catapulted images from digital cameras to become the quasi standard requirement in requests for proposals for aerial mapping projects. The availability of Near-Infra-Red (NIR) information allows digital cameras to be used for classification and monitoring tasks, such as species classification, crop assessment, water stress evaluation, micro farming or feature classification.

3. CONCLUSIONS

In talking about the versatility of DMC, this paper has discussed different aspects. Economy of use is gained through modular design, widest field of view for all digital large format cameras and designed reliability. A wide operating range is supported by the high radiometric sensitivity of the CCD-array together with the pixel size of 12µm and the forward motion compensation by electronic time delayed integration (TDI), increasing the amount of time available for flight missions. Quick project turn around times are supported by an optimized workflow and the system's ability to process image data using a distributed processing environment to reduce processing of 2000 images to less than 24 hrs.

Coming back to the idea to represent the world with layers storing "visual information" and "spectral information", DMC can contribute in a perfect sense. Adding "height information" and "descriptive information" is the task of the subsequent processing or data evaluation steps, where DMC imagery easily interfaces to.

For Intergraph, the DMC system was the missing piece to offer an end-to-end Earth Imaging Solution, starting from Data Acquisition (DMC) and Data Compilation (ImageStation), through Data Classification within Geo Information Systems (GIS) (GeoMedia) to Data Distribution (WebMap) and Data Management (TerraShare), to vitalize Intergraph's vision to "*help organizations see the world clearly*".

4. REFERENCES

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