TEN YEARS LARGE FORMAT DIGITAL AERIAL CAMERAS, A REVIEW

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ABSTRACT

Large format Digital aerial cameras were introduced 10 years ago in Amsterdam at the ISPRS Conference in July 2000. Only about 5 years later the digital large format aerial cameras had overtaken the majority of photogrammetric image production. The new technology did change the photogrammetric workflow, replaced well known components and made the end-to-end all digital production chain available to the photogrammetric community. Helpful if not essential was the development of computers, storage media, software products and other IT components which are the basis of any digital processing scenario.

The development of large format digital aerial camera shows a specific evolution. Frame size, multi spectral capability, on board storage capacity and other details of such sensor systems are discussed within this contribution. The impact on the productivity of photogrammetric production units, the number of frames taken by one sensor during one year and the increasing appetite for geo data are as well topics of this article.

Furthermore we discuss the development of photogrammetric software solutions and their ability to handle large volumes of pixel data. The need for automation and the introduction of new photogrammetric products are in focus. As a contribution to further discussions we try to give an outlook for the next few years and to ask ourselves the question if the photogrammetric community is well prepared for the next decade.

KEY WORDS: Photogrammetry, Digital, Camera, Large Format

INTRODUCTION

Photogrammetry developed quite fast as soon as digital technology was introduced and many improvements could be achieved through software. New products from the information technology industry contributed as well. Larger storage space, faster processing as well as effective data transfer components shall be mentioned.

Even if this technology was quite helpful to improve throughput and quality of the photogrammetric processing chain the film based source data acquisition was still the only alternative for aerial mapping projects until the last five to ten years.

The first presentation of large format digital aerial cameras at the ISPRS Conference in Amsterdam in July 2000 opened the door into the era of the end to end all digital photogrammetric processing chain.Four or five years later digital aerial cameras were able to take over the majority of the world wide photogrammetric production and to replace the film systems.Different design concepts of large format digital aerial cameras have been presented during these first decade and changes in the production line took place. The amount of digital data did grow and the handling of many TeraByte if not PetaByte in a production environment is no longer a challenge.

Fast processing after a flight mission with productive sensors and automation during the photogrammetric production chain has become a requirement in order to satisfy the hunger for geo data. Not only as a data base for experts the aerial image has become a common source of geo information for everybody as soon as web based services started to offer such data. Without digital camera technology such data could not be offered at such scale.
One specific camera design was presented in 2003 by Vexcel Imaging GmbH (Leberl et al., 2003). This concept led to a series of sensors with a continuous increase of the sensors image format. The UltraCam family of digital aerial cameras was well accepted in the mapping market and also serves as the main aerial sensor for the Microsoft BINGMaps photo acquisition.

DESIGN CONCEPTS AND NOMENCLATURE

Frame Camera vs. Line Scanner

Two different design concepts of digital aerial cameras are available on the market. One type is offering a set of frame images taken from a number of discrete positions and one is using linear CCD sensor arrays and a continuous data capture mode along the flight path. The frame based concept has the advantage to feed into a traditional photogrammetric workflow with a well known environment, offers image based orientation and aero-triangulation capabilities and a diversity of different exposure settings. The line scan cameras relate their technology background to the experience in remote sensing application and exploit the improvements in direct sensor orientation. Were frame cameras enable a traditional image based orientation the linear CCD sensors offer the three line concept were nadir and forward / backward registration is implemented.

Multi Cone Cameras vs. Single Cone Cameras

The majority of large format digital aerial cameras in operation are frame cameras. As the productivity and thus the frame format has been identified as the key parameter of a large format camera it is obvious that single CCD sensor arrays yet do not offer the proper size to fulfill such requirements of a production camera. This was and is the reason for a number of multi cone design concepts which have been used to develop and manufacture large format digital frames. When some cameras show a dual or quad cone concept with slightly oblique optical axes the UltraCam sensor technology is based on a set of nadir facing camera cones. This concept is illustrated in the flowing paragraph.

Large Format vs. Medium Format

The separation between large format cameras and medium format cameras is not sharp. Of course we see the ongoing development in the high end segment but also a rather large image format at some so-called medium format cameras. A very valuable overview on the actual camera product portfolio is given in (Toth, 2009) and shall be subsumed below:

Table 1. Total of camera systems and image formats as given in (Toth, 2009)

Camera Type	# of products listed	Min/Max Sensor (Frame) size (pixel)	
Large format multi head frame cameras	6	10500*7200	17310*11310
Large format line scan cameras	5	8002	14400
Medium format multi head frame cameras	4	8000*2672	7216*10000
Medium format single head frame cameras	10	4080*4080	10580*10560

The largest medium format camera system within this list is a 100 Mpixel single head/single CCD system which exceeds the smallest large format camera herein mentioned. Newest announcements allow to expecting even larger camera products based on single CCD sensors and the expression “super medium” was already heard. Beside the nadir- or near nadir facing cameras the mapping community exploits a handful of oblique camera systems which may be counted as medium format multi head cameras.

Direct Sensor Geo Referencing

Direct sensor orientation is based on the GPS and IMU technology and has been successfully introduced into the aerial operation and photo acquisition process. Such technology helps to improve robustness and performance the image based aerial triangulation but also enables photogrammetry to serve as a rapid response data capture technology. This emerging need for real a time or near real time application also influences the ongoing camera and on board storage and data processing development.

Software Leveraged Hardware

The concept of software leveraged hardware is beneficial to any end to end digital workflow. One good example is the ability to automatically introduce the result of a hardware calibration activity into the processing chain without any additional manual interaction. Beyond such optimization new concepts of data acquisition and more complex processing methods can be anticipated.

ULTRACAM

Sensor Design and Sensor Evolution

The first implementation of this large format digital frame camera was introduced in 2003. The so called UltraCam D offers an image format of almost 90 Megapixel. The basic concept of the sensor unit consists of a set of eight camera heads. Four of them contribute to the high resolution panchromatic image. Four cones contribute to the multi spectral image.

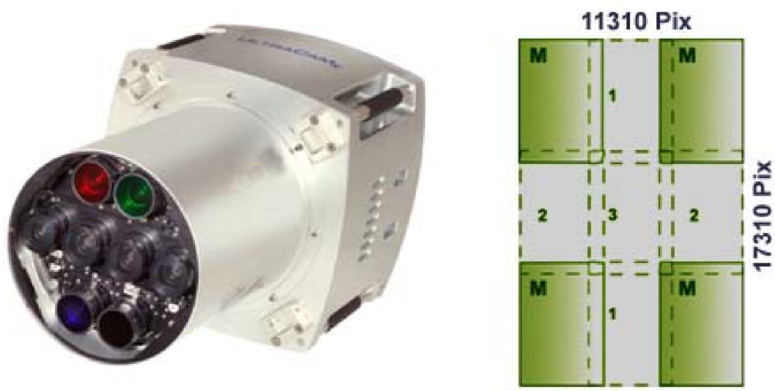

Figure 1. Sensor head of the UltraCam large Format Aerial Camera System (left).
The design concept is illustrated on the right. Four cones (M, 1, 2, and 3) with 9 CCD sensor arrays contribute to the panchromatic image.

The basic design concept of the UltraCam large format sensor remains unchanged Thus the number of lens cones and CCD sensor arrays is the same for UltraCam D, UltraCam X (Gruber, 2007), UltraCam Xp and UltraCam Xp wide angle. These individual products were introduced into the market in 2003 (UltraCam D), 2006 (UltraCam X) 2008 (UltraCam Xp) and 2009 (UltraCam Xp wide angle) and show a continuous increase of the footprint size as well as the increase of onboard storage space at 1.4 TByte in 2003 and 8.2 Tbyte in 2008.

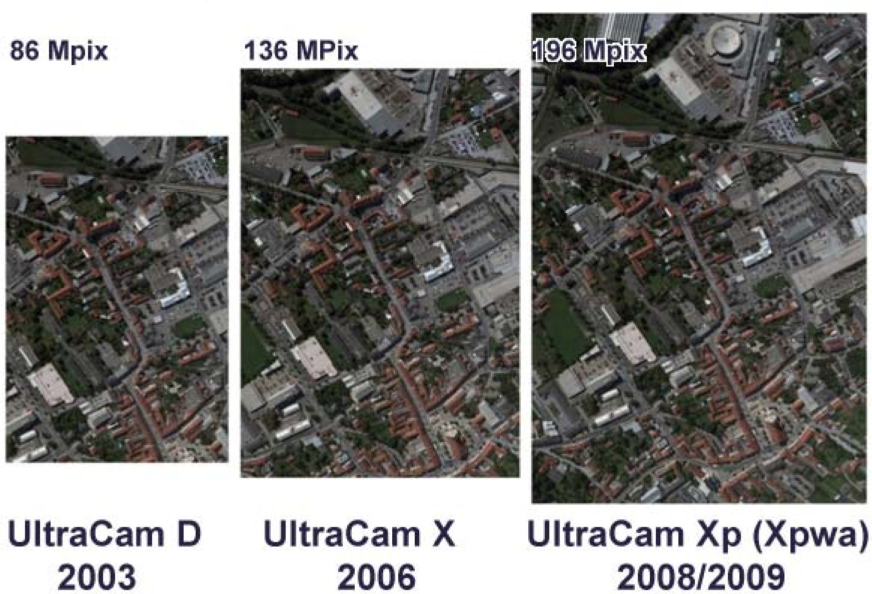

Figure 2. The UltraCam large format camera evolution: from left to right UltraCam D (2003), UltraCam X (2006) and UltraCam Xp (Xp WA) (2008, 2009). The image format improved by a factor of 2.3,
the storage capacity improved by a factor of 5.3 within a period of 5 years.

Software Components

The main software components of any digital camera system are those to operate the camera in the air and to process images after the flight mission. UltraCam's on board Camera Operating System COS was optimized and adapted for the larger image formats of the new camera. The post processing software is embedded into the UltraMap Platform. The UltraMap visualization engine Dragonfly is based on Microsoft Seadragon technology and is designed to ease the handling of the large amount of thousands of UltraCam image data by using tiled image pyramids and graphics card acceleration. This allows fast access to multi-resolution image data.

Nevertheless the core software technology of such camera system is the multi CCD image post processing kernel. In case of the UltraCam system it contains and makes use of the entire calibration information of the camera and exploits redundant image information to transform the individual image patches from the individual CCD sensor arrays into one single frame image. Improvements within this specific technology have been presented and the so-called monolithic stitching approach was published. The concept combines redundant information from overlapping CCDs of the panchromatic sensor as well as from color channels and tunes geometry as well as radiometry of each image.

Photogrammetric Processing

An additional advantage of the end to end digital workflow is the ability to streamline and optimize a specific processing chain. Thus the UltraMap AT aero-triangulation software exploits such option and offers the aero-triangulation functionality at an early post-processing step at 16 bit radiometric bandwidth and level 02 image format. Not only the content of on single frame, also the use of multiple overlaps could be introduced into the photogrammetric project design. Thus robustness is improved and the degree of automation is enhanced.

The UltraMap software suite is tuned to process large quantities of pixel data from UltraCam images. Thus the system is designed for parallel processing at a larger computer environment to improve the throughput. For smaller projects and for immediate QC tasks abroad the package is able to work on a small computer as well.

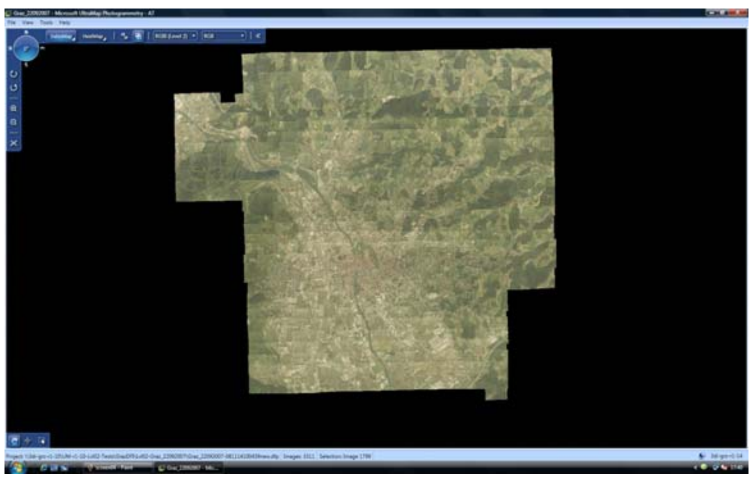

Figure 3. The UltraMap – Dragonfly GUI enables the operator to control large amounts of image data. This block of 3300 UltraCamX images consists of 428 GPixel or 2.5 TeraByte of digital Data.

Computing Environment

Throughput has become an issue for wide area mapping. When projects did contain a few hundred images, interactive processing on single core computers did not cause a remarkable bottleneck. Today mapping companies is ready to handle projects of many thousand aerial images and terabytes of digital image data. A powerful computer environment is therefore mandatory. The information technology industry supports such needs by offering parallel computing architecture solutions which are tuned to accelerate any raster data processing (Nvidia, 2009). The new "cloud computing" concept offers computing capacity and resources on demand for heavy duty computing tasks (Leymann, 2009). No question that such developments will be of interest for wide area mapping projects.

LARGE FORMAT CCD SENSOR ARRAYS

The size of CCD sensor arrays is improving constantly but not as fast as other components of the information technology industry. The law of Moore describes a 2 year cycle where the linear scale of electronic components doubles. In the case of CCD's we observe a cycle of 5 years or even more. The today's largest framing CCD offers a size of 100 Megapixel, even larger arrays are announced.

This leads to the assumption that large format digital aerial cameras at the medium or “super medium” format will be available for mapping and aerial photogrammetry application in the near future but large format systems will be build on a multi CCD design concept at least for a period of some more years.

SPECIAL CONCEPTS

It is obvious that any image data can be introduced into a digital and thus highly automated processing chain. Image analysis allows to exploiting such images in order to retrieve geometric and radiometric information and convert raw pixel data in value added mapping products. Adding information from GPS/INS sensors makes such process robust.

One among others – the Vision Map A3 Airborne Camera System (Pechatnikov et al., 2009) – does show such new approach. In the case of the A3 system a minimum number of cameras are combined with a mechanical actuator which moves the cameras in order to increase the swath width. Software to control the system in operation as well as software to post-process the large number of individual images completes the system. A very different design concept is implemented in the *‘Arched Retinal Camera Array’* by M7 Visual Intelligence (Guevara, 2009). And finally the Sony Gigapixel approach shall be mentioned as the extreme concept of a multi cone camera system (NewScientist, 2007).

CONCLUSIONS

Digital large format cameras have been announced ten years ago and did find their way into the photogrammetric source data acquisition. Today the final gap within the all digital workflow and all digital processing chain is closed. During this decade a number of different design concepts for digital cameras were presented and the community observed an increase of the magnitude of the photogrammetric production. New applications like web services based on photogrammetric data did influence and expand the common need for such digital data. The ambition to increase productivity in the air has been acknowledged and digital aerial cameras show larger footprints than ever. IT industry contributed with larger storage media, faster data transfer components and rigidity of on board devices. Based on this valuable components software will continue to play a significant role towards higher productivity and new and challenging applications in photogrammetry and mapping.

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