UltraCam and UltraMap – Towards All in One Solution by Photogrammetry

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ABSTRACT

This paper introduces the new flagship of the digital aerial camera industry for remote sensing. Vexcel Imaging GmbH has developed and announced a new UltraCam camera, the so called UltraCam Eagle. This camera defines a new bucket in the digital aerial camera market: the ultra-large format camera segment. The paper gives an overview about this new camera system. In addition, new features of the processing software UltraMap towarde an all-in-one solution by Photogrammetry are described.

1. ULTRACAM

1.1. Introduction

Digital aerial cameras have basically replaced analog cameras for all kind of applications. Since the first digital cameras came to the market, a constant increase of frame size or more generic: an increase of the amount of pixel across the flight strip took place. That development was driven by the need of increased flight efficiency to minimize flight costs, minimize flying time and to minimize project risk.

The key parameter for the collection efficiency of a digital aerial camera is the number of pixel across flight strip. This directly impacts the number of flight lines required to map a certain area. The number of pixels along the flight line has no or only very little impact on the collection efficiency because this can always be offset by a fast frame rate and an automated processing workflow. Since years, cameras are segmented into buckets such as medium format or large format cameras. The new UltraCam opens a new bucket, the ultra-large format bucket. Figure 1 shows the segmentation of the current available digital aerial photogrammetric cameras.

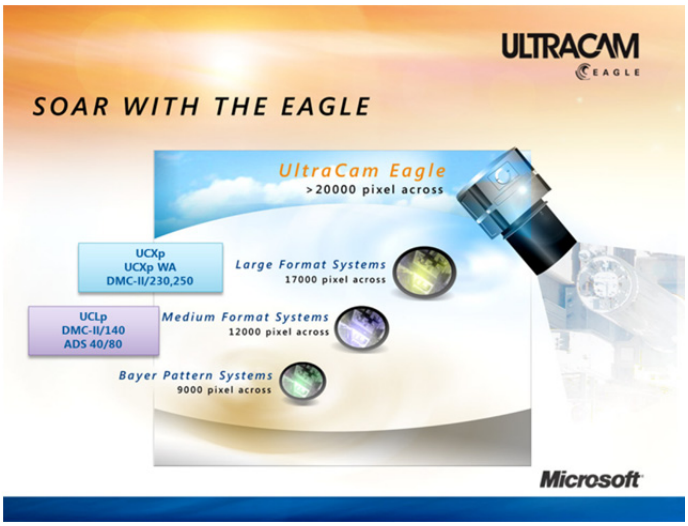

Figure 1: Camera Segmentation

1.2. Ultra-Large Format Camera UltraCam Eagle

As already mentioned above, the key parameter for collection efficiency is the amount of pixels across the flight strip. The UltraCam series has always been an innovation driver of the industry. Figure 2 shows the frame size development of the UltraCam camera series since 2003. It ranges from UltraCamD (2003), to UltraCamX (2006), to UltraCamXp and UltraCam Xp Wide Angle (2008 and 20009) to the most recent model, the new ultra-large format UltraCam (2011).

Figure 2: UltraCam frame size (UltraCamD, UltraCamX, UltraCamXp, new UltraCam Eagle).

With a frame size of 20,010 pixels across the flight strip @ full stereo capability, the new ultra-large UltraCam Eagle defines again the standard of the aerial camera industry. The camera has new lenses, two different lab exchangeable lens systems, new CCDs, new filters, new electronics for a fast frame rate of < 1.8 seconds, a new storage system and a new camera flexible modular housing concept.

The new UltraCam Eagle is a radical new camera system; each component has been rigorously reviewed and newly developed to the extent of today's technological limits, however it is based on the well proven camera design of the former UltraCam models such as the UltraCamX or UltraCamXp. The PAN channel is stitched together by Monolithic Stitching from nine overlapping sub-images. The nine sub-images are exposed by syntopic exposure which results in a parallax free image.

Due to the high integration, all components are integrated into the sensor head and no additional storage or computer unit is required. With this, the new ultra-large UltraCam Eagle follows the new architecture which has already been introduced with the UltraCamL in 2008.
Another key parameter for the collection efficiency of a camera is image dynamic or radiometric dynamic. The higher the image dynamic of an aerial camera is, the better the camera can handle different illumination conditions. The capability to handle lower illumination conditions extends the flying hours per day and also allows flying under cloud coverage. That leads to more flight hours per day and to more flight days per year. Image dynamic also directly impacts image quality and measurement quality. The higher the image dynamic is, the more details are visible e.g. in the shadow. That leads to more and more robust tie points during AT or photogrammetric measurement.

The use of nine newly developed smaller CCDs for the PAN channel of the new UltraCam Eagle ensures best image dynamic, superior to the dynamic of monolithic large CCDs. Also, monolithic large CCDs require multiple readouts to obtain a somehow acceptable frame rate. These multiple readouts split monolithic large CCDs into several non-overlapping tiles. So, the radiometry of a large CCD is not at all monolithic. The smaller CCDs of the UltraCam have higher signal to noise ratios which leads to higher image dynamic. Radiometric, the big footprint of the UltraCam is stitched together out of only nine overlapping sub-images by Monolithic Radiometric stitching implemented into UltraMap.

The new UltraCam features a b/h ratio of 0.34, which is a very suitable value. Due the rectangular aspect ratio of the UltraCam and the fast frame rate, collection efficiency and geometric accuracy by b/h ratio are well balanced. The nine sub-images of the PAN channel are stitched together by Monolithic Geometry implemented into UltraMap with sub-pixel accuracy. Values of 0.8 µm to 1.0 µm are constantly achieved by UltraCams and with Monolithic Stitching also independent from the image content.

Processing of ultra-large format images require a tailored workflow. UltraMap features a highly automated workflow and features such as automated distributed processing, automated load balancing, automated level 0 to level 2 and level 2 to level 3 processing enable the end user to process quickly and to deliver high quality results fast.

2. ULTRAMAP

2.1. Image Processing

The amount of data collected by digital cameras is huge. The new ultra-large format UltraCam Eagle image size is around 842 Mega Byte per capture. UltraMap is the processing software for all UltraCam cameras. It extends the workflow into a full photogrammetric workflow by a seamless integration of aero triangulation and bundle adjustment functionality into the existing image processing workflow. UltraMap is designed to handle all kind of projects ranging from projects with a few hundred images up to projects with thousands of images and it is optimized for UltraCam images. For this, it introduces a new, revolutionary technology and concept of image handling, a direct spin off from the latest available Microsoft technology.

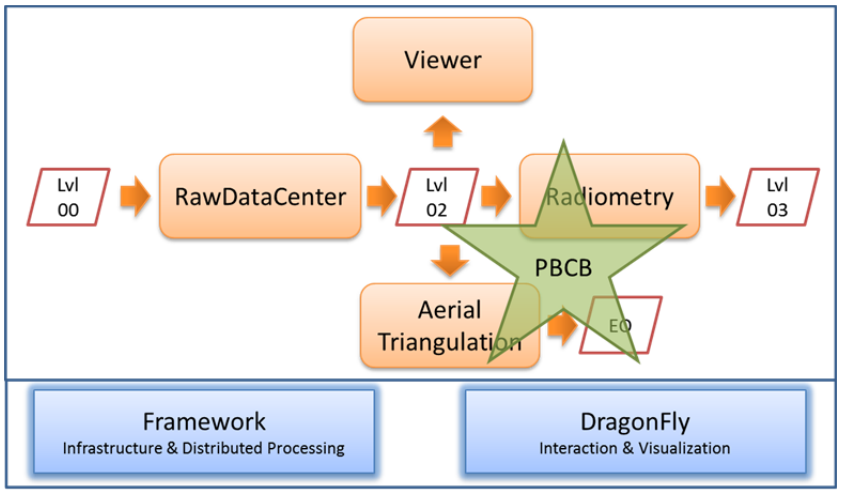

Figure 3: UltraMap image processing overview.

UltraMap offers all the features to process ultra-large format images efficiently and to deliver high quality results in time. Key is the workflow oriented innovative workflow featuring:

- Automated verified fast download of image data into the processing system
- Automated distributed processing level 0 to level 2 featuring Monolithic Geometry
- Automated distributed processing level 2 to level 3 featuring Monolithic Radiometry
- Automated load balancing
- Embedded aerotriangulation with automated tie point collection

- Automated blunder removal during bundle adjustment
- Automated project based color balancing (PBCB)
- Model-based radiometric correction such as hotspot, atmospheric effects, and haze
- Dragon fly based viewer
- Full 16 bit workflow with multi-camera support

2.2. Dense Matching

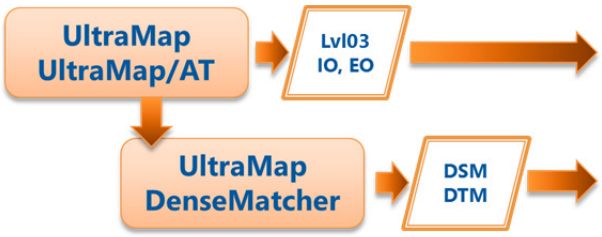

Figure 4:. UltraMap Dense-Matcher module.

With the upcoming version of UltraMap, the Dense Matching exclusively developed by Vexcel Imaging GmbH for Microsoft's Virtual Earth and BING maps projects will be implemented as an optional module and made available to the UltraCam community (Figure 4). This Dense Matcher is based on the so called Multi-Ray Photogrammetry. Multi-Ray Photogrammetry is not exactly a new technology, rather a specific flight pattern with a very high forward overlap (80%, even 90%) and an increased sidelap (up to 60%). The result is considerable redundancy, critical for robust automated matching. One pixel on the ground is visible in up to 12 images. Such a dataset allows automated "Dense Matching" to extract surface models from the imagery.

Figure 5: A series of high-overlapping 10cm GSD images resulting in a dense surface model (>50 points per square meter) through automated dense matching

Once the DSM has been processed from the imagery, a filtering and classification process – comparable to the filtering and classification of elevation models acquired by Lidar scanning – can be applied to achieve the terrain model (DTM). The images below show a greyscaled relief of the DSM (left) and the DTM (right). The DSM has been processed using UltraMap software and a set of UltraCam images. The DTM has then been processed out of the DSM using a "Winston-Salem" algorithm developed by Microsoft.

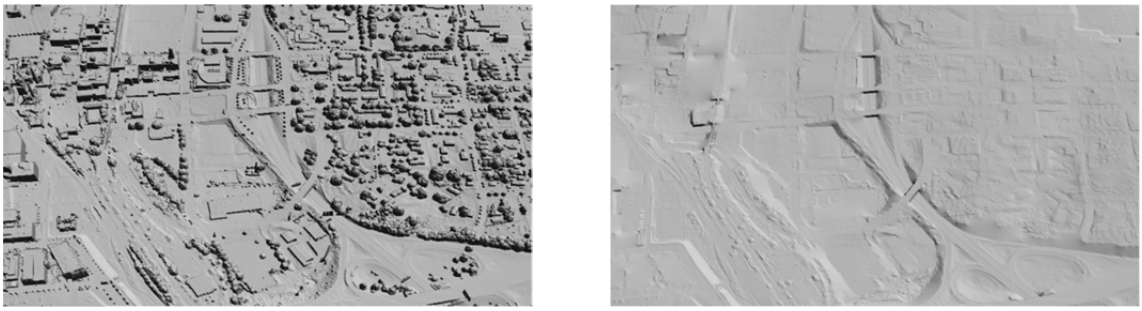

Figure 6: High-resolution DSM (left) and DTM (right) processed using automated dense matching with UltraCam images and UltraMap processing software

This shows that high-resolution DSM and DTM production is no longer a domain of Lidar scanning and can also be accomplished through photogrammetry and the UltraCam. In most applications, Multi-Ray Photogrammetry achieves a significantly higher point density with superior collection efficiency. The achievable height accuracy is better than the GSD, thus a 10cm imagery leads to <10cm height accuracy of the DSM. The quality of the automated dense matching process depends significantly on the camera and the structure of the terrain. Geometric stability and radiometric dynamic of the camera have a direct impact on the matching results. Due to the substantial amount of pixels collected by a digital camera (a 10cm GSD image has 10x10 = 100 pixels per square meter), an average dense matching ratio of 50% results in a DSM with a point density of 50 points per square meter. This is significantly higher than the point density of a typical Lidar project and the swath with of such a project flown with the UltraCam Eagle would be remarkable 2 km in width.

2.3. UltraMap Ortho/True-Ortho Workflow

As an extension to the UltraMap workflow, an optional Ortho/True-Ortho module will become available (Figure 7). This module takes the input data sets of the previous UltraMap modules such as images, AT, DSM, DTM and processes ortho or true-ortho images automatically. The figure 8 below shows an example of a DSM derived from UltraCam images and the related true-ortho image. The image on the left shows a grey shaded relief of the dense DSM that was processed by automatically matching the digital imagery from the UltraCamL flight. The grey values represent height information. The right image shows the true-ortho image that was then processed by overlaying the raw imagery with the dense DSM.

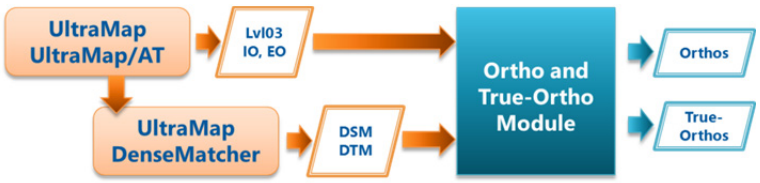

Figure 7: UltraMap Ortho/True-Ortho module.

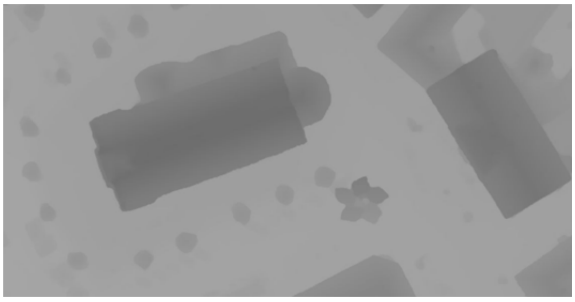

Figure 8: High-resolution DSM

10 cm GSD True-Ortho Image

Noticeable is the extremely sharp edge representation in the DSM due to the high point density achieved through the automated matching of the high-resolution imagery. The result is that the true-ortho imagery shows almost no artifacts in spite of the 10 centimeter high-resolution GSD.

In summary, the Multi-Ray Photogrammetry approach extends the capability of photogrammetry for applications currently being served through Lidar scanning. The combination of UltraCam and UltraMap allows not only the acquisition of aerial images but also an automated point-cloud and DSM generation from the digital images through robust dense matching. Due to the superior collection capacity of digital frame cameras, the frame-image based DSM generation leads to higher point densities at lower collection costs when compared to Lidar scanning. A DTM can be

processed by applying filtering and classification comparable to the filtering of Lidar data for the DSM. These data sets can then be used to automatically generate ortho images or true-ortho images of high resolution.

3. REFERENCES

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