

RADIOMETRIC QUALITY OF ULTRACAM-X IMAGES

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ABSTRACT:

The large digital frame camera UltraCamX was introduced in 2006 by Vexcel Imaging (a Microsoft Company). This paper will give a short technical overview about the concept of the camera and more information on the radiometric quality of the UltraCamX. The focus in this paper is set on the radiometric quality of the sensors. Already recorded image data are analyzed in detail for their radiometric performance. In addition, some experiments with color targets have been performed to show the radiometric performance of the camera. The results of both analyses are presented in this paper.

1. INTRODUCTION

This paper represents the results of an analysis of the radiometric quality of the UltraCamX camera system. The sensor is equipped with high performance CCD sensors FTF5033 manufactured by DALSA. Nearly 13 bits of radiometric information can be extracted and transformed via a 14 bit analog/digital converter. This bandwidth allows resolving dark and bright areas within one image even if bright sunshine and dark shadows exist.

This paper presents the results of a radiometric analysis of five different camera units and will give a short outlook onto a future implementation for color calibration and transformation.

During the development of the UltraCamX the hardware was improved as well as the post processing software. Noteworthy is the special shutter release feedback and a dynamic aperture model.

1.1 UltraCamX – technical overview

The UltraCamX large format digital aerial camera system was introduced in 2006 and is the successor of Vexcel's UltraCamD. The basic concept of the design did not change. The sensor unit consists of eight camera heads. Four camera heads build the large format panchromatic image, another set of four camera heads collect the color information in red, green, blue and near infrared (cf. Figure 1). The resulting images have a size of 14430 by 9420 pixels and can be recorded at a frame rate of 1 frame in 1.35 seconds. Thus high forward overlaps can be achieved at a reasonable speed of the aircraft and a large image scale.

The physical dimension of the image is 103.9 mm by 67.8 mm at a Pixel size of $7.2 \mu\text{m}$ by $7.2 \mu\text{m}$. The principal distance of the camera is 100.5 mm.

The data storage system of the camera can store almost 4700 frames redundantly on two separate Data Units. All image data are digitally stored at 16 bit bandwidth.



Figure 1 – Sensor head of UltraCam X digital aerial camera system with 8 cones and five spectral bands (pan, RGB and NIR). The multi spectral cones are equipped with color filters.

2. DATA

The UltraCam sensor head is equipped with four multispectral camera cones with color volume filters in order to separate different color bands of the incoming light. Thus each color band is sensed from a separate camera head. Multi band color images like true color RGB are then produced within the postprocessing of the images. This includes geometric registration of color bands onto the panchromatic large format channels as well as corrections for any specific camera setting.

Two different types of analysis were performed:

In a first test already existing image data from different areas were analysed in detail. Two different examples of an urban area and a high mountain area with glaciers are presented below in chapter 2.1 and 2.2

In chapter 2.3 the setup for the experiments in the calibration laboratory is described in detail. This experiments was performed at five UltraCamX sensors.

2.1 Example Urban Area

Figure 4 presents a first image sample to show the radiometric performance of the sensor in urban areas. The figure shows a frame from a test flight over the city of Graz, Austria on March 27th 2007, a clear sunny day. At a flying height of 900 m above ground level a ground sampling distance (GSD) of 6.5 cm was achieved. Two sub areas of the panchromatic camera head containing very bright objects (umbrellas and welded roofs) as well as dark shadows were analyzed by computing the histogram. Levels of intensity from 350 DN to 7800 DN @ 16 bit could be detected without saturation. Such huge dynamic range of 7450 DN corresponds to almost 77 dB or 12.9 bit.

2.2 Example Glacier

The image presented in

Figure 5 was recorded on August 4th 2007 in the Swiss Alps on early afternoon on a clear and sunny day (the image was provided by FMM GesmbH, Salzburg, Austria). The radiometric range in this image shows grey levels from 474 DN to a maximum of 7896 DN. Again this corresponds to a bandwidth of 12.9 bit (or 12.2 bit S/N).

On the right side of Figure 5 we show a detail and a grey level profile. The wide radiometric range starts at a DN of 488 and ends up at a maximum of 7804 DN.

2.3 Experiment

In order to proof the radiometric performance of the UltraCamX sensors under laboratory conditions we designed an experiment with a color target. The results of this experiment are used for the development of a color calibration concept as well.

The experiment was set up in the calibration laboratory as it can be seen in Figure 2. The camera was mounted on the camera calibration cart with the camera viewing downward. The color target was At the bottom of the calibration a mirror was mounted

We used a standard light wall with 6500K as light source which was positioned behind the camera. As we are aware of the fact that this light source was powered with alternating current we recorded the images with special exposure times to be independent of the light jitter. In addition, we performed some tests outside the calibration laboratory with daylight and no artificial light source and the same setup..

For each exposure time and aperture setting a set of 20 images in a row were recorded. After post processing the images were averaged to avoid any further influence of the light source.

The UltraCam post processing software OPC (Office Processing Center) version 3.2.0 includes such advanced functionality including the consideration of shutter release feedback as well as a dynamic aperture model. All recorded images from the laboratory experiment were processed with OPC version 3.1.4

(excluding these new functions) as well as OPC version 3.2.0. The results of this analysis clearly show the improvements of

the new features. Only those results processed with OPC version 3.2.0 are presented here in this paper.

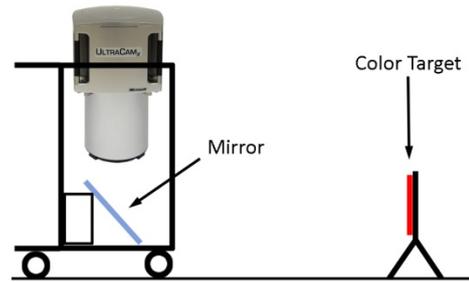


Figure 2 - Set up of the Color Stability Tests

Figure 3 shows the color target we used for the tests. This target was especially manufactured for Vexcel Imaging and shows a fraction of the Kodak IT8 color target.

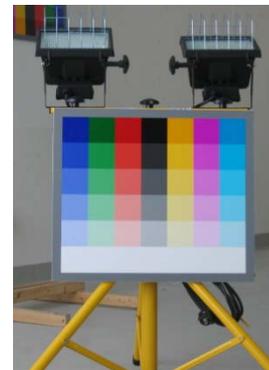


Figure 3 - Color Target

3. ANALYSIS

The analysis of the image data from this experiment showed a very good radiometric stability of the UltraCamX sensor heads. Each square of the color target was averaged and the resulting intensity levels were compared according to their exposure time and aperture settings.

We performed this test with five different cameras and the results are very similar. Below in

Figure 9 a diagram shows the mean value of the central white color target (row with black to white neutral). The x-Axis represents the image number (for each aperture and exposure time setting 20 images have been recorded) and the y-Axis represents the DN. The images have been processed and radiometrically corrected. These corrections are available from the standard camera calibration and handle the dark current as well as the vignetting effect. The data shown in Figure 9 present Level01 data processed with OPC version 3.2.0. This includes besides the above mentioned processing steps a correction of the shutter release time as well as a dynamic aperture model.

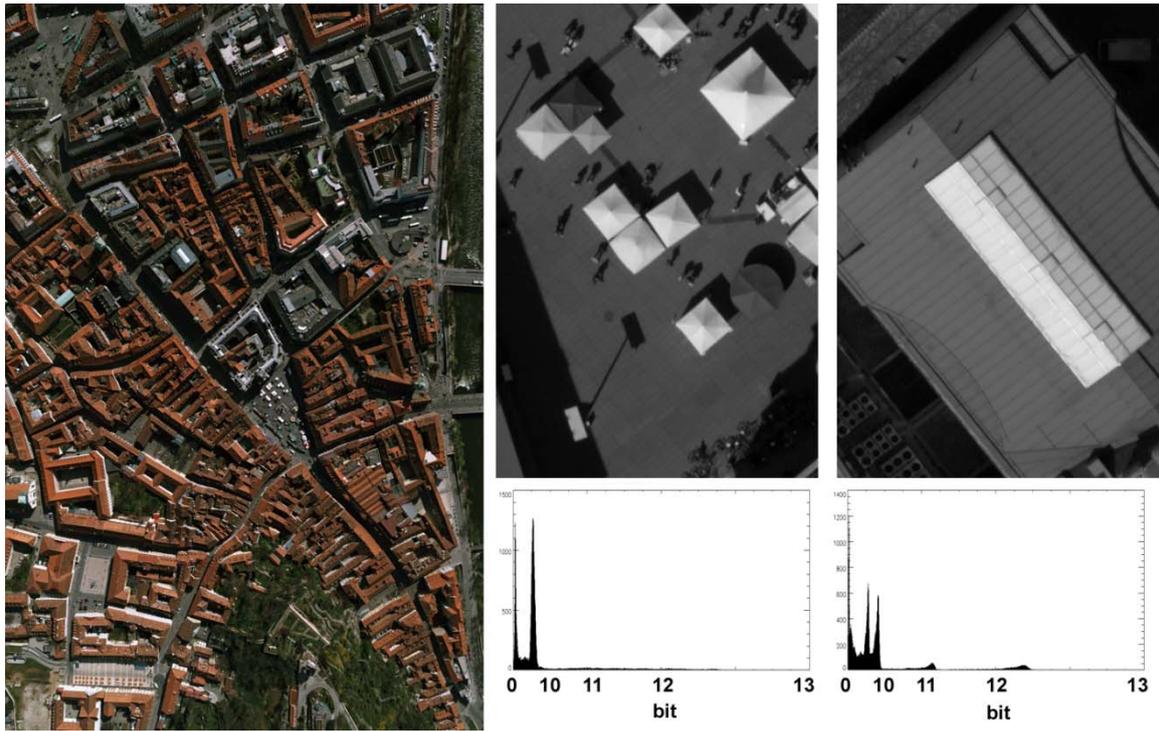


Figure 4 – Urban area with bright roofs and dark shadows. The histogram shows grey levels beyond 12 bit.

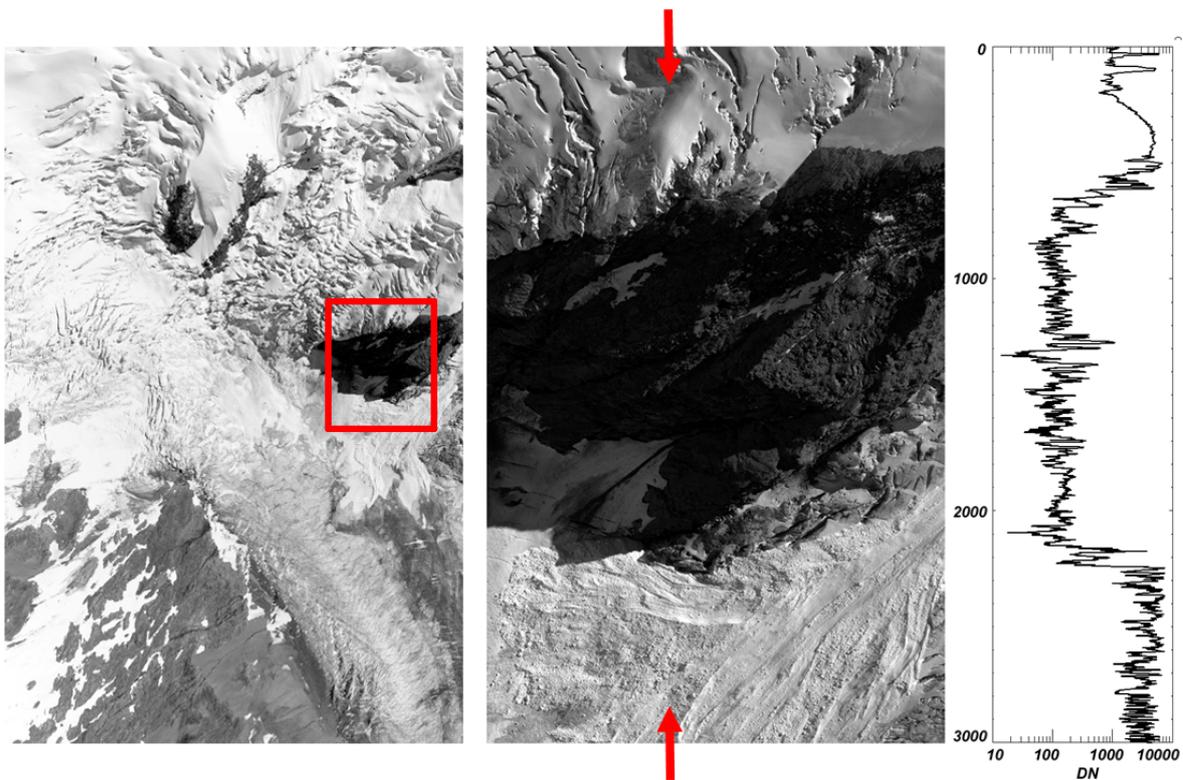


Figure 5 – High mountain area with bright ice fields and dark shadows. The profile on the right shows almost 7500 grey levels.

The results shown below have been recorded under daylight conditions in order to avoid jitter effects of any light source. The enlargement of the diagram illustrates that the intensities are stable within only a few DN's (+/- 2DN) in all five channels. Table 1 presents an overview of the analysis and shows the standard deviations of all intensity measurements within all images patches of the color target at settings f5.6 - 1/250 sec and f8 - 1/250 sec (f-stop and exposure time). The standard deviations were detected to be below 1.3 within a 16 bit scale.

Standard Deviation		
	F5.6	F8
	1/250	1/250
Red	1.09	1.03
Green	1.22	0.62
Blue	0.40	0.47
PAN	0.93	0.57

Table 1- standard deviation values for red, green, blue and pan channel

Figure 9 shows as well that the ratio between aperture and exposure time works very well. The sensitivity is approximately the same when decreasing the exposure time from 1/250 to 1/125 and changing the aperture appropriately from f5.6 to f8. Also is the sensitivity reduced by a factor of 2 when closing the aperture from f5.6 to f8. The linearity of the radiometric response of the UltraCamD sensorhead at flight conditions has been evaluated within a field experiment by Honkavaara and Markelin and shall be mentioned herein.

When displaying the red, green and blue values in a 3D diagram the linearity of the color channels can be shown.

Figure 10 shows the red, green, blue, cyan, yellow, magenta and black target field displayed in 3D (x-Axis - red, y-Axis - green and z-Axis - blue). All seven colors are approximately linear. The different values arise from the different exposure time and aperture settings. In this case the result of another camera is shown which were recorded in the calibration laboratory with the above mentioned setup.

4. COLOR TRANSFORMATION

The reflective color target which was used for the experiments is based on the Kodak IT8-Target. With such known color values it was possible to continue with our investigation.

Figure 6 below shows four different images of the color target. The upper right image is the original UltraCam Level01 image. The upper left image is the already transformed UltraCam image and the lower left image shows the image of the color target exposed by a Canon EOS small format camera with a color CCD. On the lower right side the RGB transformed image of the color target created from the known color coordinates.

The image of the Canon EOS is already quite good. Only in the last column (blue to white) it can be seen that the blue is too bright. This is due to a slightly sidewise illumination of the target.

The UltraCam image as processed without additional settings is slightly darker and we observed that the yellow column

contains too much red. When applying the color transformation this can be reduced and the resulting image fits to the color target (lower right).

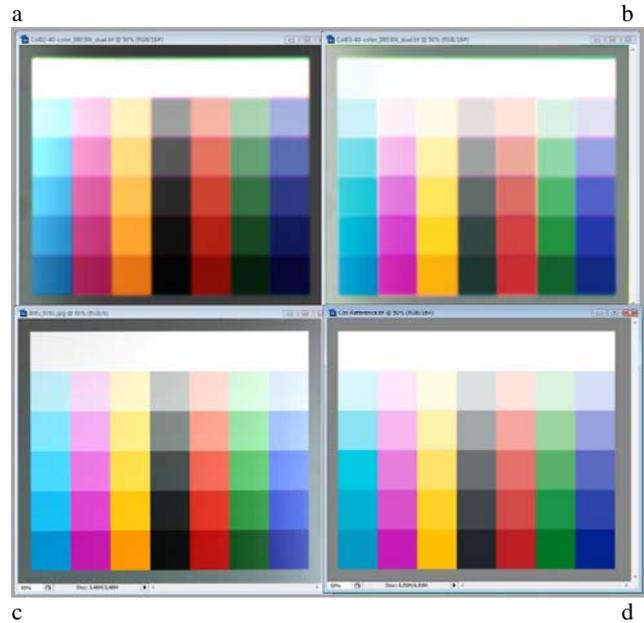


Figure 6 – (a) UltraCam Level01 image, (b) Corrected UltraCam image, (c) Canon EOS reference image and (d) artificial color target

The color transformation used in this case consists of three coefficients for red, green and blue. In total we compute for each color channel a 1x10 vector of coefficients. This coefficient vector is computed for all three color channels as well as for all cameras we have performed our radiometric tests in the calibration laboratory. The variation of the factors concerning different cameras, different aperture and exposure time settings, is being analyzed at the moment.

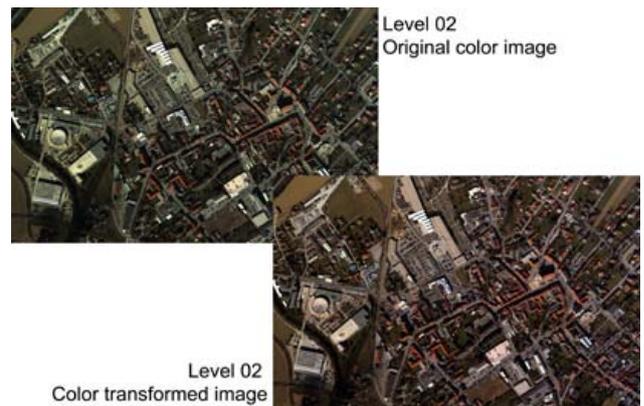


Figure 7- Comparison of original and transformed color image

Figure 8 illustrates results from such color transformation applied to an aerial image. The source image is shown on the upper left. The result from the transformation is shown on the lower right.

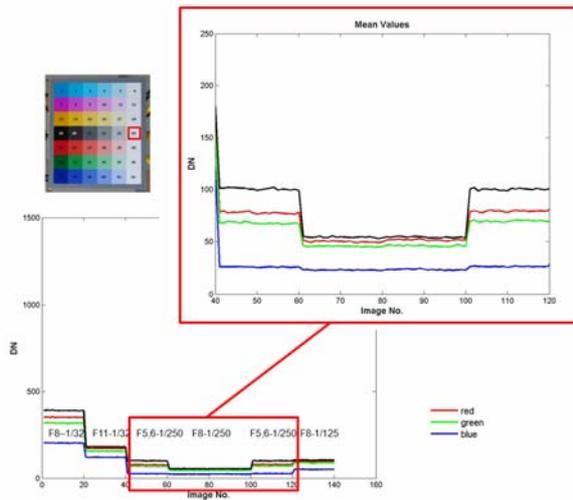


Figure 9 - Mean Value of a white color target in a line chart incl. zoom to show the stability

5. RESULTS AND DISCUSSION

The radiometric bandwidth of the UltraCamX sensor head was documented by images from high contrast scenes. It is obvious that the camera is able to resolve dark shadows as well as bright areas without saturation. Such bandwidth is the basis for all ongoing processing steps and offers headroom for color balancing. The experiment in the calibration laboratory showed that the color channels are linear and stable with respect to different f-stop and exposure time settings. New features of the post processing software (OPC version 3.2.0) like the shutter release feedback and the dynamic aperture model improve the radiometric stability as well.

In a further step first tests with a color transformation method were evaluated. The first results are very stable and. Further tests will show if this method is the appropriate one to be integrated in our post processing workflow to compute color calibrated images.

The results of such color calibration will clearly have a benefit to the user by means of an enhanced workflow. Especially when more than one UltraCam sensor is used for a single project it is of interest to produce even colors for the final output.

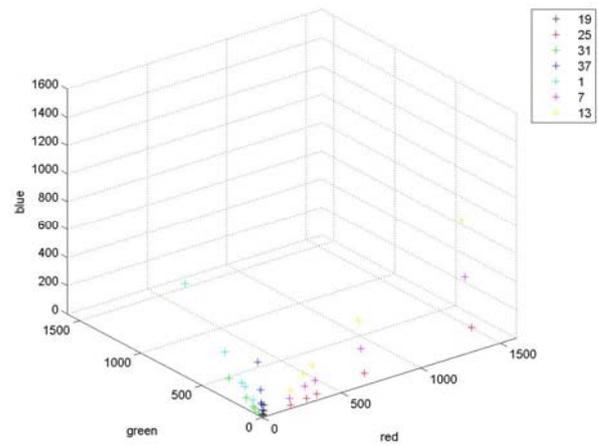


Figure 10 - red green and blue values displayed in a 3D-diagram

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