RESULTS FROM ULTRACAM MONOLITHIC STITCHING

Michael Gruber, Richard Ladstädter
Vexcel Imaging Austria / Microsoft Photogrammetry
Anzengrubergasse 8/4, 8010 Graz / Austria
{michgrub, rladstae}@microsoft.com

ABSTRACT

We present results from the post-processing methodology of the multi head digital aerial frame cameras UltraCam also known as monolithic stitching. The process is implemented in the so-called UltraMap Platform Software Suite and consists of three major steps: the introduction of the laboratory calibration data set, the stitching process including POI selection and image matching within overlaps of sub image footprints and the adjustment of the highly redundant set of image measurement

Within the post-processing of each frame after the flight mission the transformation parameters between layers of the multi cone design are computed via the stitching method. This stitching method includes observations from the panchromatic camera as well as physical parameters of the camera body and additional observations from the color cones of the multi head sensor system. The geometric accuracy of the images is presented via data sets from production flights and illustrates the high quality of the method.

KEY WORDS: Photogrammetry, Digital, Camera, Large Format

INTRODUCTION

Vexcel Imaging GmbH has introduced its multi cone camera product family since 2003 which is well known since then and has successfully made its way into to market. The basic idea was introduced in (Leberl et al., 2003) shows a 4 cone concept for the large format panchromatic image. In 2008 the UltraCam L was presented. This camera is based on a slightly modified concept with two camera heads for the large format pan image. As a company motto Vexcel has focused on software to control the sensor in a sophisticated manner and to meliorate the product in line with its concept of “Software Leveraged Hardware”. The outcome of that software development are a smooth workflow and high quality production images from a robust and accurate post processing namely the so called “Monolitic Stitching” which was introduced in 2010 (Ladstädter et al., 2010).

Figure 1. Sensor head of UlraCam Xp (left) and UltraCam L (right).

RESULTS FROM TWO FLIGHT MISSIONS

We present the results from two flight mission from the different sensors, the UltraCam Xp and the UltraCam L. Both flight missions were flown over a well know area with sufficient structure on the ground. Thus the post processing could access well-structured image content and therefore identify sufficient tie points. The focus on this analysis was the geometric quality of the final image data set and the impact of redundancy from different flight layouts. In line with that experimental focus a full set of images with good overlap and cross strips was modified and for both cameras 3 sets of images were introduced into the automated aero-triangulation and least squares bundle adjustment procedure.

The first derivative of the full data set was achieved by removing the cross strips. From the almost 50 % side-lap a certain level of redundancy was still available. Most of the manually measured ground control points and check points could be identified in 5 or 6 images from two adjacent flight lines. The second derivative was then generated by removing every second flight line from the block and therefore eliminating any cross track connection. Still most of the manually measured points could be identified in 3 images of one and the same flight line.

This method was applied for both cameras and comparable test sets were generated.

UltraCam Xp

The flight mission consists of 235 shot positions at five flight lines north to south and three flight lines east to west. The flying altitude of 900 m AGL leads to a ground sampling distance (GSD) of 5.4 cm. Thus the footprint size of the 196 Megapixel camera is about 935 m by 610 m. The base length was set to 200 m (~70% end lap), the distance between flight lines was 500 m (~ 50% side lap). 20 control points and 9 check points were used to verify the geometric performance of the camera. In order to analyze the effect of redundancy we reduced the number of flight lines and thus three sets of 235, 160 and 96 images were introduced into the bundle adjustment (see Fig. 1).

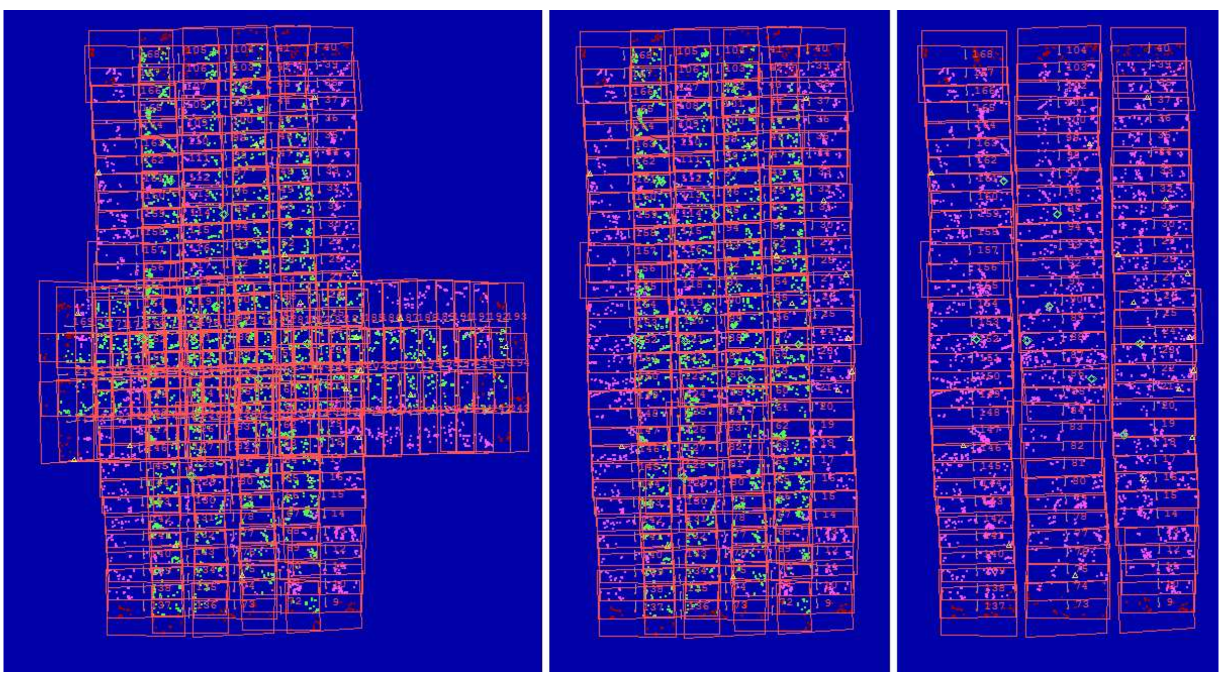

Figure 2. Layout of the flight mission UltraCam Xp: Full set of 8 flight lines (left) 5 north-south lines (center) and 3 lines without cross overlap (right).

Table 1. Results from the flight mission UltraCam Xp: Full set of 8 flight lines (Set 1) 5 north-south lines (Set 2) and 3 lines without cross overlap (Set 3).

Set 1, 8 lines, 235 images, GSD 54. mm

SIGMA 0 = 0.82

	X[mm]	Y[mm]	Z[mm]
RMS values of check point residuals	27.	21.	41.
RMS control point residuals:	28.	19.	45.
RMS GPS residuals:	29.	32.	16.
	P[mg]	O[mg]	K[mg]
RMS IMU residuals:	4.0	3.4	3.5

Set 2, 5 lines, 160 images, GSD 54. mm

SIGMA 0 = 0.78

	X[mm]	Y[mm]	Z[mm]
RMS values of check point residuals	28.	23.	25.
RMS control point residuals:	27.	23.	31.
RMS GPS residuals:	27.	36.	16.
	P[mg]	O[mg]	K[mg]
RMS IMU residuals:	4.4	2.7	3.4

Set 3, 3 lines, 96 images, GSD 54. mm

SIGMA 0 = 0.70

	X[mm]	Y[mm]	Z[mm]
RMS values of check point residuals	43.	25.	27.
RMS control point residuals:	36.	22.	39.
RMS GPS residuals:	28.	20.	8.
	P[mg]	O[mg]	K[mg]
RMS IMU residuals:	3.8	2.3	2.9

Results from the least squares bundle solution from these 3 experiments are illustrated in Table 1. The internal accuracy of these three sets is at the 1/8 pixel level, represented by the sigma _o value. Of further interest is the magnitude of the residuals at individual check points. This was identified at a level of ½ Pixel for x, y and z as well.

UltraCam L

The flight mission is similar to the latter one and consists of 273 shot positions (six flight lines north to south and three flight lines east to west). The flying altitude was 700 m AGL and the ground sampling distance (GSD) is 7 cm. The base length was set to 200 m (~70% end lap), the distance between flight lines was 390 m (~ 50% side lap). 35 control points and 20 check points were used to verify the geometric performance of the camera. In order to analyze the effect of redundancy we reduced the number of flight lines and thus three sets of 235, 160 and 96 images were introduced into the bundle adjustment (see Fig. 1).

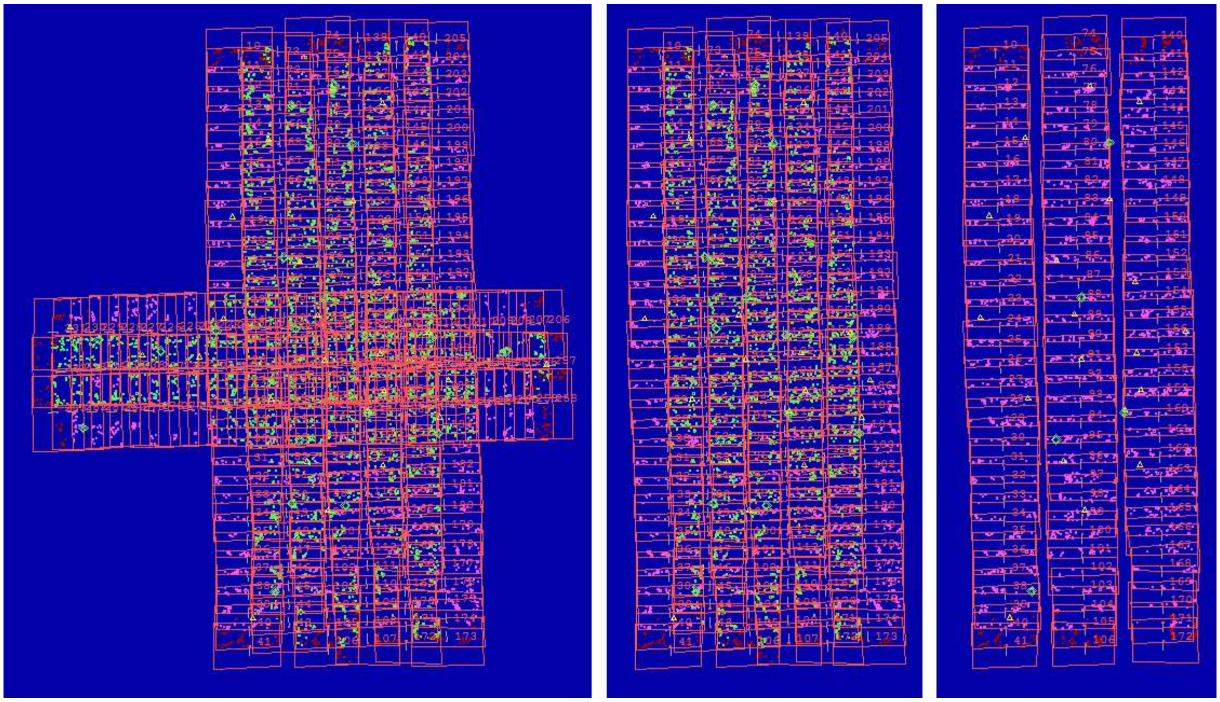

Figure 3. Layout of the flight mission UltraCam L: Full set of 8 flight lines (left) 6 north-south lines (center) and 3 lines without cross overlap (right).

Figures 2 and 3 illustrate the flight layouts of the two photo missions. The similarity between the mission for UltraCam Xp and the mission for UltraCam L is obvious. The number of automated tie points is comparable as well (UltraCamXp Set 1: 6772, Set 2: 5257, Set 3: 3807 and UltraCam L Set 1: 7425, Set 2: 5730, Set 3: 2645). The change of color (green to pink) for tie points indicates the loss of cross strip connectivity (cf. Fig. 2 and Fig 3. right side).

Table 2. Results from the flight mission UltraCam L: Full set of 9 flight lines (Set 1) 6 north-south lines (Set 2) and 3 lines without cross overlap (Set 3).

```
Set 1, 9 lines, 273 images, GSD 70. mm

     SIGMA 0 =        0.97

                                           X[mm]    Y[mm]   Z[mm]
     RMS values of check point residuals     35.      33.     49.
     RMS control point residuals:            19.      21.     20.
     RMS GPS residuals:                      40.      39.     19.
                                           P[mg]    O[mg]   K[mg]
     RMS IMU residuals:                      7.2      5.6     9.2

Set 2, 6 lines, 195 images, GSD 70. mm

     SIGMA 0 =        0.91

                                           X[mm]    Y[mm]   Z[mm]
     RMS values of check point residuals     26.      31.     51.
     RMS control point residuals:            24.      21.     30.
     RMS GPS residuals:                      47.      40.     18.
                                           P[mg]    O[mg]   K[mg]
     RMS IMU residuals:                      8.0      4.3     8.5

Set 3, 3 lines, 98 photo, GSD 70. mm

     SIGMA 0 =        0.72

                                           X[mm]    Y[mm]   Z[mm]
     RMS values of check point residuals     21.      20.     62.
     RMS control point residuals:            15.      17.     11.
     RMS GPS residuals:                      48.      41.     14.
                                           P[mg]    O[mg]   K[mg]
     RMS IMU residuals:                      7.0      3.9     7.9
```

Results from the UltraCam L flight mission and the 3 data experiments are illustrated in Table 2. The internal accuracy was found at the 1/8 pixel level, represented by the sigma _o value (note, that UltraCam L Pixel size is 7.2 µm vs. UltraCam Xp and 6 µm). The magnitude of the residuals at individual check points was identified at a level of 1/3 to1/2 Pixel for x and y where residuals in z are slightly larger (2/3 Pixel).

RESIDUALS IN THE IMAGE PLANE

The effective way to analyze the high quality of the image geometry is to compute the remaining image residuals. In order to exploit high redundancy for this analysis the complete set of images was used (Set 1 containing 235 images for UltraCam Xp and Set 1 containing 273 images for UltraCam L).

The magnitude of the RMS residuals for image measurements were identified at 1/10 Pixel (x/y: 0.6 µm / 0.6 µm) for UltraCam Xp and 1/9 Pixel (x/y: 0.8 µm / 0.7µm) for UltraCam L. A visual control of the graphical illustration of image residual over the entire frame clearly shows, that systematic image distortions cannot be identified nor CCD boarders or CCD sub areas can be detected.

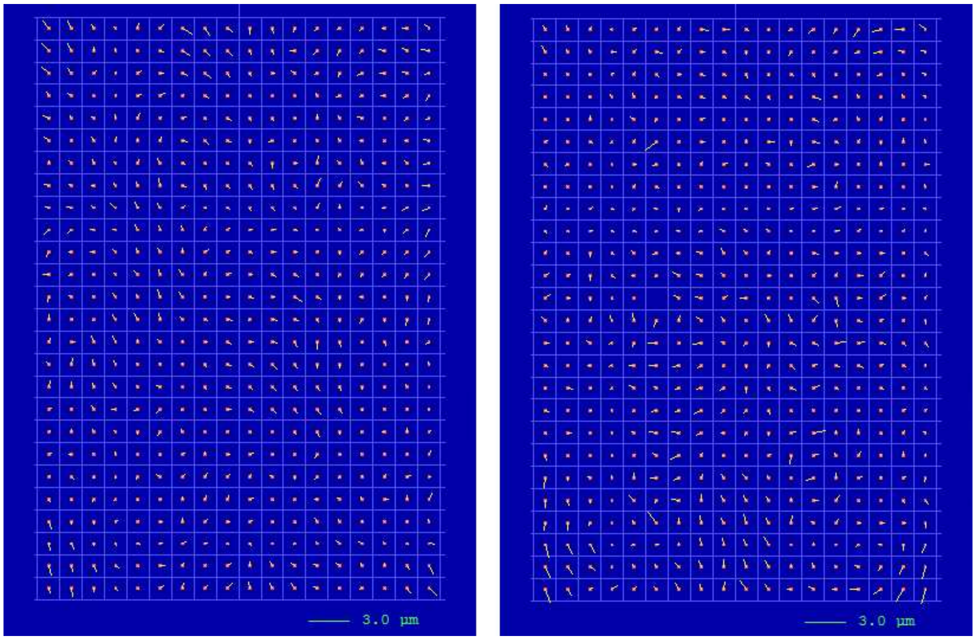

Figure. 4. Plot of remaining image residuals for UltraCam Xp (left) and UltraCam L (right). Tiling structures and / or CCD sub areas are not visible.

CONCLUSIONS

The concept of the multi cone design of the UltraCam digital aerial sensor family and the "Monolithic Stitching" software approach for image post processing are effective and reliable. Software and hardware contribute to the product in a most effective manner which was and is the guiding idea of the Vexcel product design – known as "Software Leveraged Hardware". Thus the advantage of this mature technology is high and well accepted in the community.

REFERENCES

Ladstädter et al., 2010. Monolithic Stitching: One Sensor Geometry For Multiple Sensor Cameras, *Proceedings of the American Society for Photogrammetry & Remote Sensing*, 26-30 April, 2010, San Diego, CA.

Leberl, F. et al., 2003. The UltraCam Large Format Aerial Digital Camera System, *Proceedings of the American Society for Photogrammetry & Remote Sensing*, 5-9 May, 2003, Anchorage, Alaska.