UCXp camera imaging principle and key technologies of data post-processing

Fangyan Yuan1*, Guoqing Li1, Zhengli Zuo1, Jianmin Liu1, Liang Wu1, Xiaoping Yu1 and Haitao Zhao1

1Institute of Remote Sensing and Digital Earth Chinese Academy of Sciences, Beijing, China.

E-mail: fyyuan@ceode.ac.cn

Abstract. The large format digital aerial camera product UCXp was introduced into the Chinese market in 2008, the image consists of 17310 columns and 11310 rows with a pixel size of 6 mm. The UCXp camera has many advantages compared with the same generation camera, with multiple lenses exposed almost at the same time and no oblique lens. The camera has a complex imaging process whose principle will be detailed in this paper. On the other hand, the UCXp image post-processing method, including data pre-processing and orthophoto production, will be emphasized in this article. Based on the data of new Beichuan County, this paper will describe the data processing and effects.

1. Introduction
In the 21th International Society for Photogrammetry and Remote Sensing (ISPRS 2008 Beijing), Microsoft/Vexcel company officially released the UCX upgrade version-- large format digital aerial camera UCXp, attracting a great attention. The focal length of UCXp is 100.5mm, providing an image format of 196 megapixels (17310 across track×11310 along track) and a pixel size of 6μm. The camera has innovative data storage unit DX which is exchangeable in the air. Approximate 6600 uncompressed image per DX unit (~4.2T) can be stored. New high performance lens system and top CCD technology of the world (designed by LINO Company for UCXp ) ensure the highest quality image, collection the pan-sharpen ratio of 3:1 and more colorful and realistic image. Telescopic handle design effectively reduced the size of the sensor, that more conveniently installed in a small cabin. Computing unit processes raw images on board in real time to compute quick views and histograms. The collection rate of 3Gbits per second allows collecting more data in less time, and in case of high-resolution, the camera can also obtain more overlapping images. POS system, made in Applanix Company, which is referred in this article, is capable of acquiring both GPS data and inertial measurement data during aerial photography. Joint processing of these two types of data can obtain the position and attitude data of the exposure time with high precision, e.g. the positioning accuracy of 0.05-0.30m, roll and pitch of 0.005 degrees, yaw angle of 0.008 degrees.

2. UCXp camera imaging principle
UCXp sensor unit is composed of eight high-resolution optical lenses, 4 panchromatic bands along the
direction of flight with an offset of 80mm, and four multispectral lenses arranged symmetrically on both sides of the panchromatic lenses. All lenses are in the horizontal position and the principal optic axis perpendicular to the ground. Each lens could receive sufficient light and its geometric relationship is very stable and reliable. The images would not be influenced by additional sealing the glass due to the lack of oblique lens, so UCXp can be used in the high altitude aircraft with a pressurized cabin.

2.1. Panchromatic lens imaging

The second lens of the four panchromatic lenses is the master cone, and the other three lenses are subordinate. UCXp adopts multi-lenses time-delay exposure for an object. As shown in figure 1:

![Camera imaging principle](image)

**Figure 1.** Camera imaging principle

The second lens controls the entire image to ensure the strict center projection and image rigid geometry feature. After exposure, 13 small CCD plane array collected images, panchromatic (black and white) images is composed of nine CCD images from four lenses. Internal connection structure of the well image which is formed by 12 overlapping regions is to ensure the rigor of the panchromatic image synthesis.

2.2. Color images fusion

High-resolution true color images are generated by fusing and registering the high-resolution panchromatic images and the low-resolution RGB images; while high-resolution color infrared ones are by the high-resolution panchromatic images and the low-resolution infrared images. During the fusion process, pan-sharpen ratio is a very important parameter and directly affects the quality of a color image. This ratio, the smaller the better, is 3:1 for UCXp, equivalent to 9 black and white pixels corresponding to one color pixel; panchromatic image size is 11310 by 17310 pixels, multispectral image size is 5770 by 3770 pixels.

2.3. Forward motion compensation

Aircraft Movement and the attitude change together with several other reasons cause image motion by which the image will be fuzzy, seriously affecting the image quality. There are many kinds of image motion compensation technologies. Among them, advanced TDI control technology is used in UCXp, which is up to maximum compensation of 50 pixels, enough for the application of large-scale aerial flight at high speed.

3. Data post processing
UCXp image post-processing includes three aspects: POS data processing, image pre-processing and orthophoto production. The workflow is shown in figure 2:

![UCXp data post-processing flow diagram]

**Figure 2.** UCXp data post-processing flow

### 3.1. POS data processing
Exterior orientation of the images collected by POS can provide position and attitude data of image exposure time. POS data accuracy directly determines orthophoto image accuracy, so POS data processing is a crucial step in UCXp image post-processing. Currently, there are two methods for POS processing: the differential method and Precision Point Positioning (PPP). If GPS base station data and image are collected at the same time, and the distance from field area is in the scope of 50 km, the differential method is generally chosen. In other conditions, Precision Point Positioning would be the choice. The accuracy of the differential method is comparatively higher. The POS data in this paper was processed by the differential method in Pospac5.3 the software. First, POS data was imported. Data was separated as GPS and IMU. Then GPS data was processed. Combined processing of GPS and IMU data was performed. Finally, elements of exterior orientation were exported. The accuracy of the element of exterior orientation was evaluated based on different indicators.

### 3.2. Pre-processing image
The raw data of each image consists of 13 CCD image files. They need processing by the manufacturer provided software Ultramap, including two steps: i.e. Panchromatic synthetic (L2 level) and Color Image Fusion (L3 level). During the Panchromatic synthesis processing, nine CCD images
were synthesized with embedded method. Meanwhile, multi-spectral quick views and color-infrared quick views were generated. During the color image fusion processing, fusion mode may be chosen to generate a color image, such as RGBI, RGB, Pan, etc. The color image retains both high-resolution of the panchromatic image and the multispectral or near-infrared radiation information. Therefore, it greatly improves the quality of the image.

3.3. Orthophoto correction
There are many softwares for Orthophoto production, among which LPS and ORIMA were chosen. Firstly, APM was employed in order to find homonymy points. Homonymy points accuracy was determined based on the standard deviation, reliability, etc. Then aerial triangulation can be applied. If there are ground control points in the survey area which can be measured in LPS, the aerial triangulation is implemented again to acquire more accurate element of exterior orientation, DEM is generated by rectified image. Finally, orthophoto is produced with extracted DEM or existing DEM.

4. Example and analysis
An County of Mian yang was selected as test area, especially on the new Beichuan county. The average elevation of entire survey area is 1000 m. Flight plan was designed as East-west direction strips with flight altitude 6000m, GSD 30cm, forward overlap 80%, side overlap 35%, and survey area 210 km². The flight strips were illustrated in figure3:

![Figure 3. Flight strips plan](image)

POS data was processed with the differential method. Through analysis of the quality factor, the position accuracy, the forward and backward separation and other factors, we demonstrated that elements of exterior orientation quality was excellent. Quality factor (Figure 4).

![Figure 4. Quality factor](image)
Tiff format image (L3 level), without geographical coordinate, was generated after pre-processing by the manufacturer provided software Ultramap. Figure 5 shows the new Beichuan county:

![Figure 5. New BeiChuan County](image1)

Orthophoto image was produced with existing DEM after AMP and aerial triangulation. New Beichuan county orthophoto image is shown in figure 6.

![Figure 6. New Beichuan county orthophoto image](image2)

5. Conclusions
By now, UCXp is still one of the advanced high-resolution large format digital frame cameras in the world. It has been widely used and played an important role in the earthquake monitoring during the Wenchuan and Yushu earthquakes. The camera has good expandability which works with IMU/INS and many existing mounts. In addition, the camera realizes nearly synchronous exposure and seamless image mosaic due to its internal complex imaging structure. The only shortage of this camera is the instability of the storage unit that occasional hard disk self-checking failure occurs during which cable reconnection is needed.

Acknowledgement
This work was supported by the project of Improvement research on remote sensing monitoring capabilities of disaster emergency (Funding No.Y12101101A), I would like to thank all members of the team.

References
[1] S. Malihi, M. Maboudi, M. Pourmomen 2012 MISALIGNMENT CALIBRATION OF ULTRACAM D AND XP International Archives of the Photogrammetry XXXIX-B1 577-579
[2] MICHAEL GRUBER,MARTIN PONTICELLI, 2012 UltraCam, A Brand for Continuous Developments proceedings of the Photogrammetric Week 2012 103-109
[3] Gruber, M. 2007 UltraCamx, the new digital aerial camera system by Microsoft Photogrammetry, Proceeding of the Photogrammetric Week 2007 137-145
[4] Gruber M. Ladstadter, R. 2011 results from UltraCam Monolithic Stitching Proceedings of the American Society for Photogrammetry & Remote Sensing 1-5
[5] Lebera, Fet al. 2003 The UltraCam Large Format Aerial Digital Camera System Proceedings of the American Society for Photogrammetry & Remote Sensing 5-9
[6] Wiechert A, Gruber, M 2009 Vexcel Imaging GmbH – Innovating in Photogrammetry UltraCamXp, UltraCamLp and UltraMap, *proceedings of the Photogrammetric Week 2009* 27-33

[7] Alexander Wiechert, Michael Gruber, Martin Ponticelli 2011 Ultracam: The New Super-large Format Digital Aerial Camera. *American Society for Photogrammetry and Remote Sensing* 1-5