High Accuracy Digital Surface Model (DSM) Generation, Orthorectification and Mosaicking Using Phase One Aerial Cameras

Philip Cheng

PCI Geomatics, 90 Allstate Pkwy #501, Markham, Ontario, Canada, L3R 6H3
Email: cheng@pcigeomatics.com

KEY WORDS: PhaseOne aerial camera SGM ortho

ABSTRACT: Phase One aerial cameras are a new entry to the medium format aerial camera market, with a relatively affordable price compared to other digital cameras. Comparing to large frame digital cameras, Phase One cameras have radial lens distortions which need to be taken into consideration during geometric correction. In this paper we used two mapping projects with 4cm and 10cm GSD, respectively, along with surveyed GCPs, to evaluate the accuracy of digital surface model (DSM) generated using the Semi-Global Matching (SGM) method, orthorectification and mosaicking. It was found that high photogrammetric accuracy could be achieved using Phase One cameras.

1. INTRODUCTION

During the past decade there were a few large and medium format aerial cameras available. They are widely used for mapping projects in combination with photogrammetry technology. Recently Phase One Industrial introduced new medium format camera systems that were designed from the ground exclusively for aerial photography. The biggest advantage of the medium format camera is the price is only a fraction of the large format camera. Moreover, small frame size (10x10x20cm including lenses) and extremely light weight (less than 2 kg) are significant advantages of the camera allowing an easy installation in every small and light aircraft, gyrocopters, medium size drones or UAVs. These physical attributes essentially increase the range of airborne vehicles utilized for mapping, and significantly reduces operational costs of mapping projects.

In comparing to the large format cameras, Phase One medium format cameras have radial lens distortion which need to be taken into consideration during geometric correction. In this paper we will evaluate the photogrammetric accuracy of two mapping projects using two different Phase One cameras.

2. SOFTWARE

PCI Geomatics' 2019 OrthoEngine software was used for this testing. This software supports reading of the data, manual or automatic GCP/tie point (TP) collection, airphoto bundle adjustment, automatic DSM generation and editing using normalized cross-correlation (NCC) method and Semi-Global Mapping (SGM) method, orthorectification, and both manual and automatic mosaicking with automatic cutline generation and colour balance.

In the past NCC was the most common method in extracting DSMs. The major problems with this method are blurred object borders and loss of small objects due to matching using square windows. Heiko Hirschmueller (2008) from the DLR developed the SGM method. It uses a pixelwise, mutual information (MI)-based matching cost for compensating radiometric differences of input images. SGM is among the currently-top ranked algorithms and is best, if subpixel accuracy is considered. This paper will use the SGM method to extract DSMs.

3. TEST DATA

3.1 MIDDLE EAST

The test field is situated in a village in Middle East. It covers 2.0 km form the West side to the East side of the village, and 1.2 km from the South-to the North side of the village. It is predominantly an urban area with low height of up to two-story buildings. The area is characterized by visible manmade features and manholes, which were chosen to serve as signalized GCPs. All GCPs are located on the ground.

Phase One IXU-1000-RS camera was used in this project. The 100MP cameras specifications include: pixel size of 4.6 μ, very high image capture rate -1 frame every 0.6 seconds, exposure time of up to 1/2500, a set of metric lenses with different focal lengths (50, 70, 90, 110, 150 mm). This provides an effective solution in many areas of aerial mapping, monitoring and object inspection. In this project a camera with focal length of 90mm and sensor resolution of 11608 x 8708 pixels were used. A total of 192 photos were acquired. Flight altitude above ground is approximately 760m with 4cm GSD which has an area coverage of approximately 464m x 348m per image Each camera comes with a camera calibration report. Figure 1 and 2 show examples of an overview and full resolution of an image, respectively.

Figure 1: Overview of an image

Figure 2: Full resolution of an image

Using automatic TP collection 9009 TPs were collected on all the images. The image coordinates of all 58 GCPs were manually measured. Bundle-block adjustment was performed with different number and configuration of GCPs. Photogrammetry accuracy of the block is estimated by residuals on tie points. Geodetic accuracy of the block is estimated by residuals on GCPs, which were not included during the adjustment – Independent Check Points (ICP).

Three different cases were tested. (1) 5 GCPs and 53 ICPs, (2) 9 GCPs and 49 ICPs and (3) 15 GCPs and 43 ICPs. Table 1 shows the mean and maximum ICP errors for each test.

Table 1: Mean and maximum ICP errors for different combination of GCPs/ICPs

	dX(cm)		dY(cm)		dZ(cm)	
	Mean	Max	Mean	Max	Mean	Max
5 GCPs 53 ICPs	-0.5	4.0	3.7	7.6	7.3	22.2
9 GCPs 49 ICPs	0.0	3.6	1.2	4.2	3.6	16.3
15 GCPs 43 ICPs	-0.6	4.3	0.7	3.6	1.2	10.4

Using the SGM DSM extraction method, a digital surface model (DSM) was generated using the aerial triangulation solution with 15 GCPs. The extracted DSM was also converted to DTM automatically. Both were produced at a resolution of 8cm, corresponding to 2 times the resolution of the input images. Figure 3 and figure 4 show the extracted DSM and the DTM, respectively. 33 points were selected from the ICPs. RMS Z values of 1.3cm and 1.4cm with bias error of 2.4cm and 7.7cm were obtained from the DSM and DTM, respectively. Figure 5 and 6 show examples of an image with the extracted DSM, respectively.

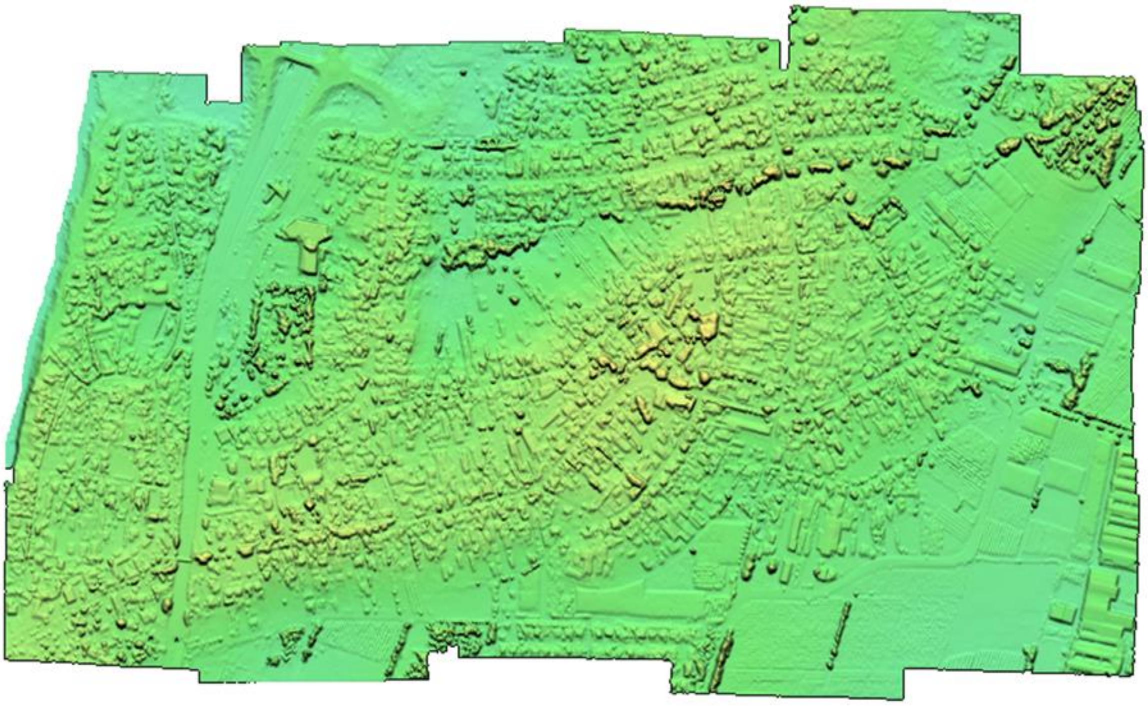

Figure 3: DSM extracted from the aerial images

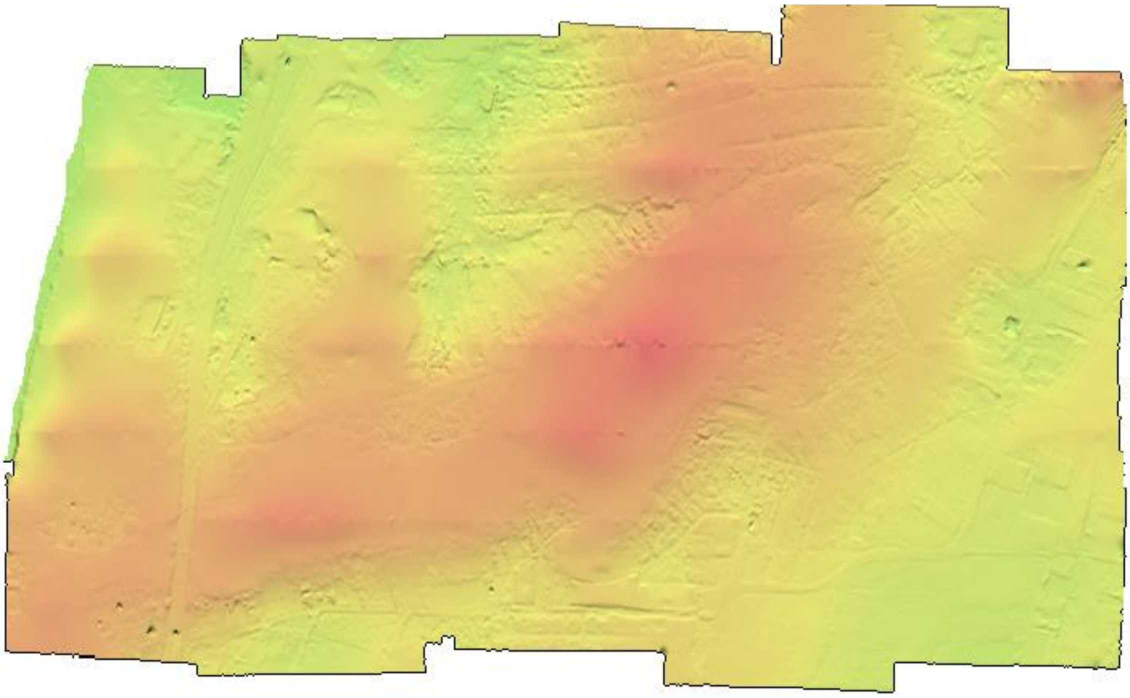

Figure 4: DSM converted to DTM

Figure 5 : Image

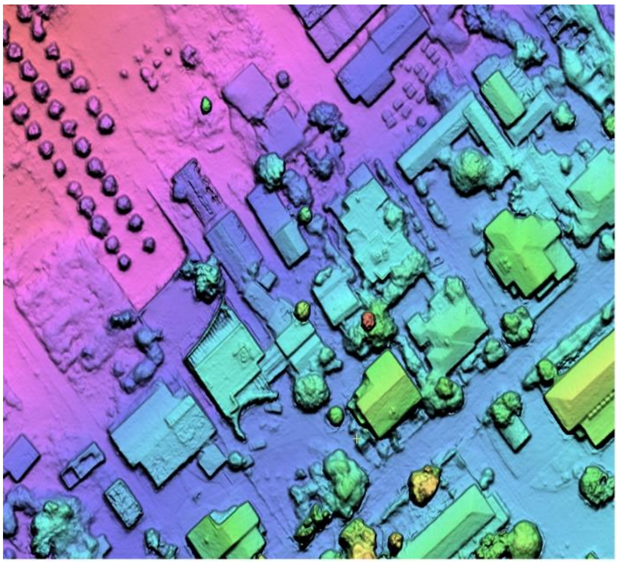

Figure 6: Extracted DSM

The individual orthophotos were created using the extracted DSM. To evaluate the horizontal accuracy, the same 33 check points used to evaluate the DSM and DTM were re-measured on the resulting 2d orthophotos. The new coordinates were extracted and compared to the original check points coordinates. The XY combined (circular) error was calculated for each point. An average of XY circular errors of 2.0cm with a maximum XY circular error of 7.4cm were obtained.

The final mosaic was assembled with the automatic colour balancing and seamlines generation. Figure 7 shows the final mosaic.

Figure 7: Mosaicked image of 192 photos

3.2 LOUISVILLE, CO, USA

The test field is situated in a predominantly residual areas with low height of up to two-story houses. The area is characterized by visible manmade features and manholes, which were chosen to serve as signalized GCPs. All GCPs are located on the ground.

Phase One IXM-RS150F camera was used in this project. A total of 60 images of 4 strips were acquired. The camera has a focal length of 51mm and sensor resolution of 14204 x 10652 pixels. Flight altitude above ground is approximately 1233m with 10cm GSD which has an area coverage of approximately 1420m x 1065m. Figure 8 and 9 show examples of an overview and full resolution of an image, respectively.

Figure 8: overview of an image

Figure 9: full resolution of an image

A total of 83 GCPs were provided with the project. 12845 TPs were collected automatically. To test the accuracy, GCPs were turned into ICPs to check the accuracy. Two cases were tested: (1) 5 GCPs and 78 ICPs and (2) 9 GCPs and 74 ICPs. Table 2 shows the mean and maximum ICP errors for each test.

Table 2: Mean and maximum ICP errors for different combination of GCPs/ICPs

	dX(cm)		dY(cm)		dZ(cm)	
	Mean	Max	Mean	Max	Mean	Max
5 GCPs 78 ICPs	-0.7	12,3	2.6	19.6	14.3	37.3
9 GCPs 74 ICPs	-2.9	11.4	-0.1	13.9	6.1	26.6

Using the SGM DSM extraction method, a digital surface model (DSM) was generated using the aerial triangulation solution with 9 GCPs. The extracted DSM was also converted to DTM automatically. Both were produced at a resolution of 20cm, corresponding to 2 times the resolution of the input images. Figure 10 and figure 11 show the extracted DSM and the DTM, respectively. 26 points were selected from the ICPs. RMS Z values of 10cm and 9cm with bias error of 5cm and 6cm were obtained from the DSM and DTM, respectively.

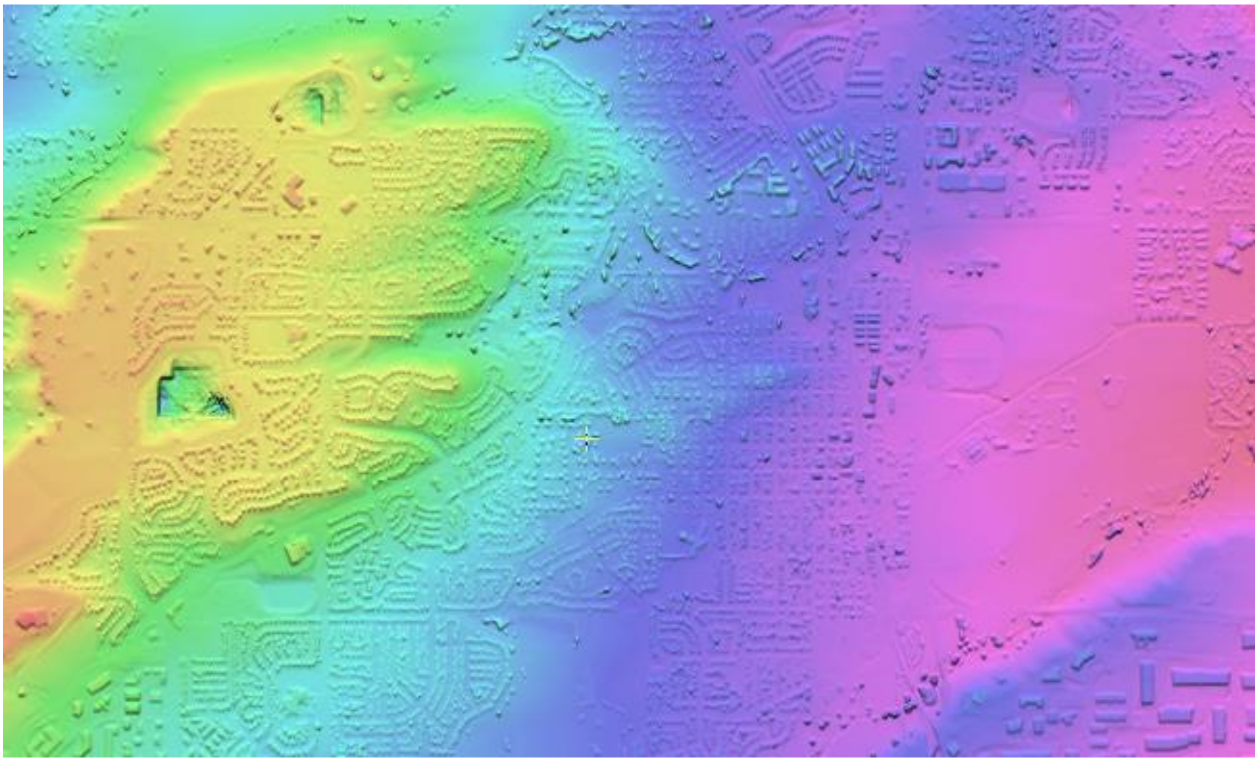

Figure 10 : Extract DSM

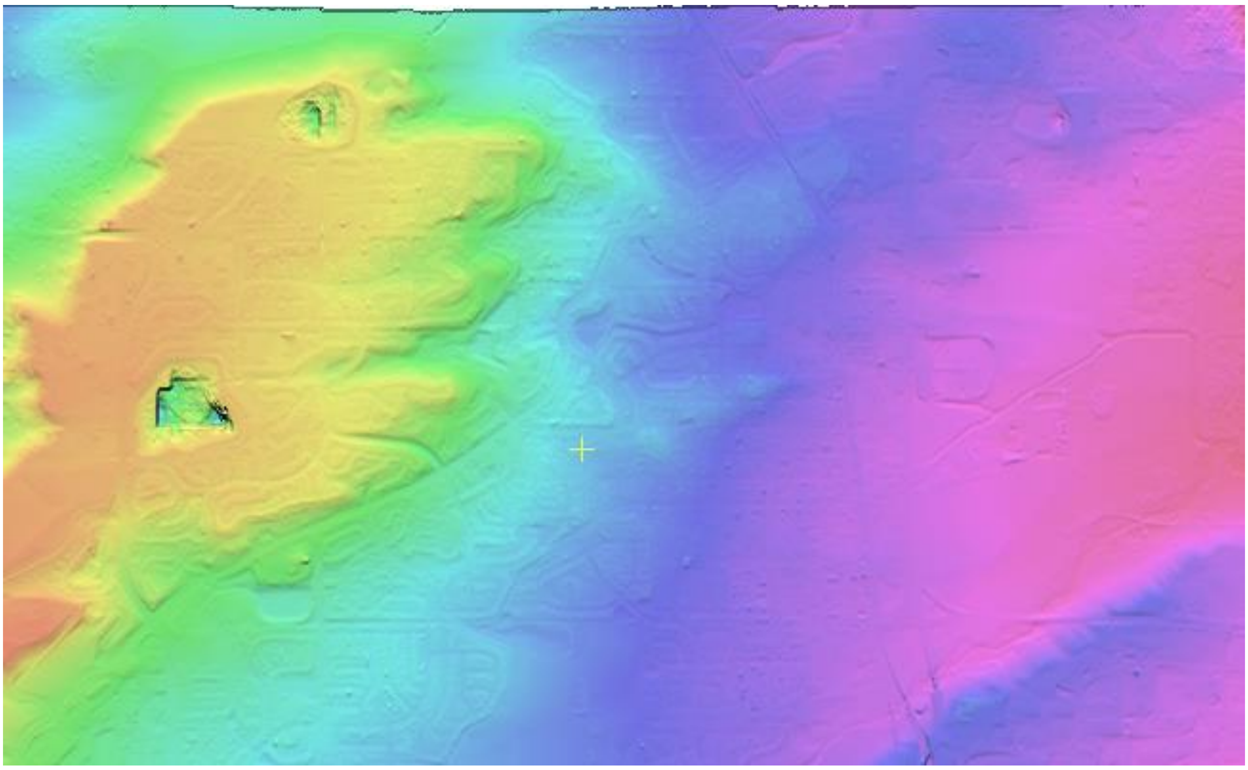

Figure 11: Extract DTM

Figure 12 and 13 show examples of an image with the extracted DSM, respectively.

Figure 12: Image

Figure 13: Extracted DSM

The individual orthophotos were created using the extracted DSM. To evaluate the horizontal accuracy, the same 26 check points used to evaluate the DSM and DTM were re-measured on the resulting 2d orthophotos. The new coordinates were extracted and compared to the original check points coordinates. The XY combined (circular) error was calculated for each point. An average of XY circular errors of 8.0cm with a maximum XY circular error of 15cm were obtained.

The final mosaic was assembled with the automatic colour balancing and seamlines generation. Figure 14 shows the final mosaic.

Figure 14 : Mosaicked images of Louisville

4. CONCLUSION

In this paper two Phase One aerial cameras were evaluated using two different projects. It was shown that using both cameras high photogrammetric accuracies were achieved. Hence, Phase One aerial cameras provide an economical alternative for mapping projects.

5. ACKNOWLEDGEMENTS

The author would like to thank Phase One Industrial for providing the test data.