Jordan Journal of Civil Engineering, Volume **5**, No. **4**, **2011**

Assessing the Performance of Different Direct-Georeferencing with Large Format Digital Cameras

Khaldoun S. Qtaishat

Civil and Environment Engineering Department, Mu'ta University, Mu'ta, Al-Karak, Jordan, 61710.
E.mail: khaldoun_q@hotamil.com

ABSTRACT

This paper provides an independent investigation into the quality, performance and reliability of the Direct Georeferencing (using in-flight control GPS and IMU systems to measure the exterior orientation parameters) with the new photogrammetric digital airborne camera systems, undertaken as a part of the German Society of Photogrammetry, Remote Sensing and Geoinfirmation (DGPF) investigation project for large format digital camera Z/I Imaging DMC and Z/I Imaging large format film camera RMC Top 15. This paper will present results from the imaging data flown at 6 different flight days over a test site in Germany during a 10 week time window starting in July till mid-September 2008. The two sensors were flown at two different flying heights, resulting in blocks with the same ground sampling distance (GSD); namely GSD = 8cm.

The results of Direct Georeferencing from real trials using a traditional Zeiss RMK TOP 15 film frame camera and Z/I Imaging large format digital camera DMC will be presented. These cameras are fitted with an Applanix POS AV 510, GPS, IMU integrated system.

In this paper, the quality of Direct Georeferencing for digital cameras and film cameras is assessed through the coordinates of independent measurement of check points. A traditional triangulation (AT) with ground control points will be performed to be used as a 'benchmark result' against which other results from direct georeferencing can be compared. The use of direct georeferencing by GPS/IMU can be distinguished in two different concepts:

- The use of direct georeferencing (DG) to measure the exterior orientation parameters for photogrammetric data processing without using the aerial triangulation.
- Direct georeferencing can be considered with aerial triangulation and the automatically measured minor control points (tie and pass points) and is called Integrated Sensor Orientation (ISO). Which approach is suitable for a specific task depends on many factors; e.g., the required accuracy and the image scale. In general, Direct Georeferencing without aerial triangulation (DG) is used for medium to small scale projects, while Direct Georeferencing with aerial triangulation (ISO) is applied to large and medium scales (Heipke et al., 2000). The results show the importance and the influence of GPS and IMU needed for Direct Georeferencing with these large format digital cameras, and how these cameras are sensitive to the accuracy of data form GPS and IMU sensors. These large format digital cameras can benefit from the higher quality of GPS and IMU data.

KEYWORDS: Digital cameras, Aerial triangulation, Direct georeferences, Integrated sensor orientation.

Accepted for Publication on 15/10/2011.

INTRODUCTION

Before the use of GPS and IMU (Inertial Measurement Unit) measurements in photogrammetry, traditional aerial triangulation was used to orient the images and to create the stereo models. The use of Direct Georeferencing radically changed things. If direct georeferencing is performed, each image is independently oriented.

The use of in-flight control systems for controlling blocks of aerial photography is now an established procedure. The technology of GPS and an inertial measurement unit (IMU) integrated with an aerial camera, either analogue or digital, is regularly being used for production purposes. The importance of GPS and IMU measurements is increasing as there is an increasing interest to work without ground control and strive towards direct georeferencing of imagery. Arguably, direct georeferencing can be considered with and without aerial triangulation as the use of automatically measured minor control points (tie and pass points) easily and efficiently undertaken by modern aerial triangulation software.

The use of automatically measured tie points is a cost effective way of generating ground control points. To measure ground control points in the field is time consuming, labor intensive and therefore expensive. So, it is efficient to minimize the measured ground control points and maximize the use of aerial triangulation generated tie points (Casella et al., 2003).

In such cases, the use of integrates GPS/IMU and digital aerial triangulation offers a possibility to achieve the required accuracy for object point determination. Therefore, using GPS/IMU data should improve the quality of tie points matching and increase the overall stability and reliability of the block.

Cramer (2003) identified some of the advantages of using direct georeferncing:

- Direct georeferencing based on GPS/IMU provides high flexibility because it can be used with any type of sensor (frame/line, analogue/digital).
- There are no restrictions on flying regular block structures.
- The direct georeferncing is an ideal method for tie point matching, even in applications where generating tie points are difficult like coastlines and dense forest regions.
- If correct GPS/IMU data processing and an appropriate overall system calibration are used, then direct determination of exterior orientation parameters using high-quality integrated GPS/IMU systems can reach high accuracy fairly close to the traditional aerial triangulation.
- Direct georeferencing without any ground control is possible, but the use of a certain number of check points in the test area itself is recommended to provide redundant data for quality assessment and quality control. If errors are present, then these check points may serve as control data to compensate the error effects.

To analyze the obtained accuracy, the coordinates of independent check points are used. The two sensors were flown at two different flying heights, resulting in two blocks with the same ground sampling distance (8 cm GSD). The 8cm GSD blocks were flown with 80% overlap conditions. The data were captured in similar test flight conditions and controlled environments, to allow for such comprehensive analysis.

The software used included Leica LPS for image point observations and automatic tie point measurement, and the Institute of Photogrammetry and Geoinformation Leibniz University Hannover Program System (BLUH) analysis tools were used to analyze results.

INTEGRATED SENSOR ORIENTATION

The use of direct georeferencing with aerial triangulation and the automatically measured minor control points (tie and pass points) is called integrated sensor orientation (ISO). Also, it can be called light integrated, because the automatically measured tie points and the exterior orientations given by in-flight GPS/IMU are used only (Casella et al., 2003). No ground control points are inserted, which is different from the traditional aerial triangulation. By giving the right weights to the in-flight GPS/IMU observations in the aerial triangulation processing, a new set of exterior orientation parameters can be determined.

The use of automatically measured tie points is a cost effective way of generating ground control points. To measure ground control points in the field is time consuming, labor intensive and therefore expensive. So, it is efficient to minimize the measured ground control points and maximize the use of aerial triangulation generated tie points (Casella et al., 2003).

TEST SITE

The DGPF project provided a data set taken at two different altitudes over a targeted (pre-marked) test site in Vaihingen/Geramny. The following block data sets were utilized within the test process, Figure 2, showing the DMC images block and the RMK TOP 15, respectively, taken at ground sample distance (GSD) of 8 cm. A flight plan was used with a nominal forward overlap of 80% and a nominal side overlap of 60% for 8cm GSD flight.

IN-FLIGHT GPS AND IMU DATA

The direct measurement of position and attitude is produced by an Applanix POS 510 GPS/IMU system using the post processing software, POSPac (4.02). The specification provided by the manufacturer for the GPS/IMU system is given in Table 1(Mostafa, 2001).

Table 1. Specification of the Applanix system POS/AV-510 for direct measurement of position and attitude

Position (m)	0.05 - 0.30
Velocity (m/s)	0.005
Roll and pitch(deg)	0.005 (1/200th)
True heading (deg)	0.008 (1/125th)

This system provides the potential for in-flight control for aerial triangulation, enabling a reduced amount of ground control to be used, or direct geo-referencing of individual images (Scholten et al., 2003).

Table 2. Results of low flight for AT, DG and ISO

Camera Name/GCP/CP	Processing method	Ground check points RMSE (m) of residuals			Image coordinates RMSE (μm) of residuals		σ μm
		X	Y	Z	x	y	
Z/I Imaging DMC/9/95	Traditional AT	0.042	0.056	0.071	1.32	1.14	1.60
	DG	0.079	0.068	0.277	1.82	1.31	1.97
	ISO	0.041	0.048	0.068	0.77	0.98	1.45
Z/I Imaging RMK Top 15 film/14/40	Traditional AT	0.114	0.125	0.080	4.86	4.49	5.20
	DG	0.241	0.178	0.281	5.74	6.32	5.56
	ISO	0.176	0.131	0.122	3.66	3.19	4.34

ASSESSMENT OF RESULTS

There are two basic ways to quantify the quality of direct georeferencing: firstly, through the measurement of check points in the stereo model and secondly by the magnitude of residual 'y and x parallax' in the stereo model; the traditional quality measure of relative orientation. Both are important from a mapping point of view and will be investigated in the following sections, the first being particularly important for manual point measurement in a stereo model (Qtaishat et al., 2006).

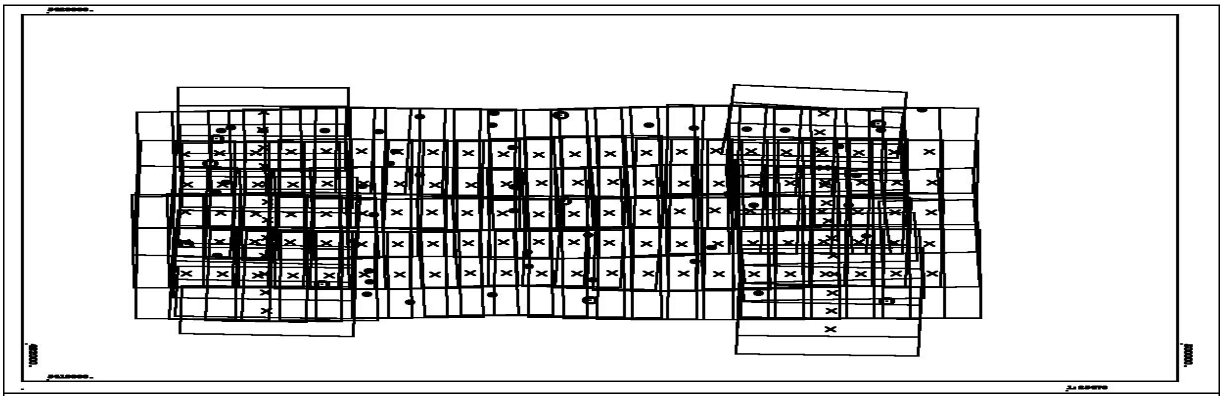


Figure 1: DMC-block with 8cm GSD

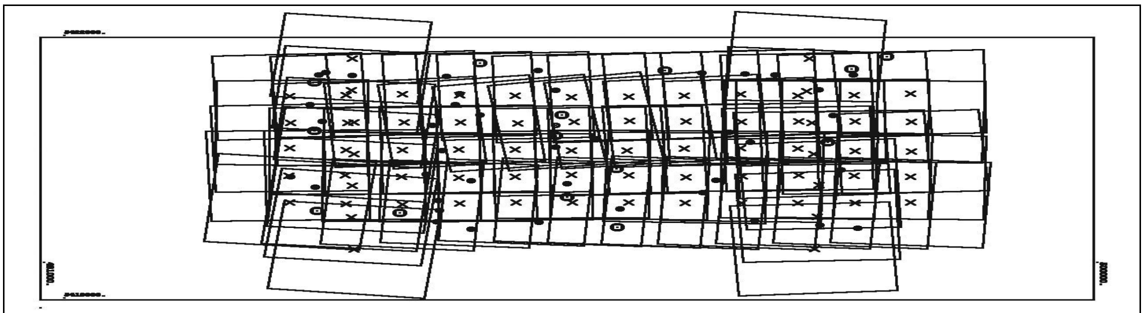


Figure 2: RMK-block with 8cm GSD

In this paper, the quality of direct georeferencing for DMC digital cameras and RMK TOP 15 film cameras is assessed through the measurement of check points in the stereo model. To check direct georeferencing exterior orientation parameters in the actual map production environment, all airborne data (imagery, GPS/IMU position and attitude and calibration parameters) were used in the direct georeferencing mode with no ground control points, in order to set up the stereo model and observe the check points in the manual stereo measurement way. Then, the resulting coordinates of these points were compared to their independently surveyed coordinates. The most important finding is that the results of direct georeferencing proved to be a serious alternative to conventional bundle adjustment (Jacobsen, 2001).

Table 2 shows the root mean square error (RMSE) and the standard deviation (Std) of the low flight results (8 cm GSD), which relate to the accuracy of ground check points (CP) in the manual stereo models for AT (Aerial Triangulation), DG (Direct Georeferencing) and ISO (Integrated Sensor Orientation) with large format digital camera Z/I Imaging DMC and large format film camera RMK TOP 15, respectively.

Table 2 shows that the residual values of check points resulting from the direct georeferencing are larger than the residual values of check points resulting from the integrated sensor orientation by approximately a factor of 3 in the height coordinates due to the increase of the x parallax. This reduction in the quality of check points in the direct georeferencing solution is probably due to the transformation parameters for the

GPS coordinates and the quality of the calibration of integrated sensor offset parameters.

Figure 3 and Figure 4 show the size of the image residuals which is usually exaggerated to emphasize the trends. Figures 3 and 4 show the image residuals of the three configurations (AT, ISO and DG) for Z/I Imaging DMC and Z/I Imaging RMK Top 15, respectively.

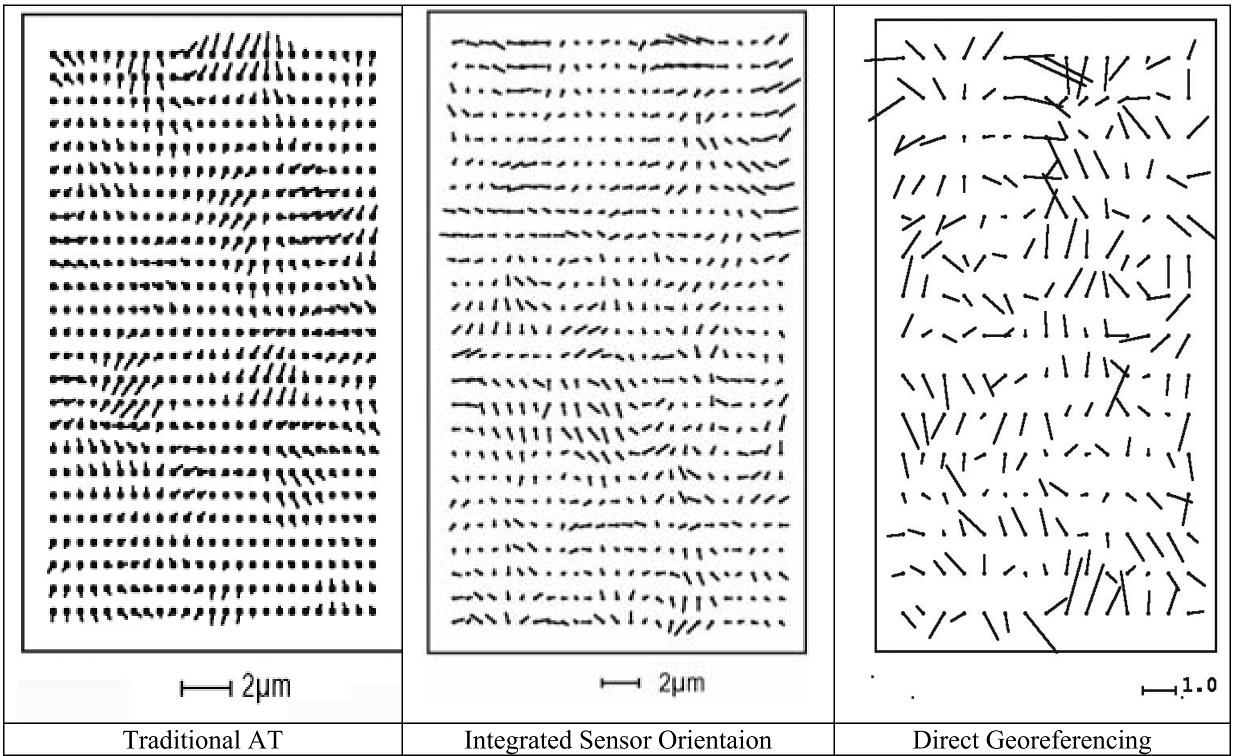
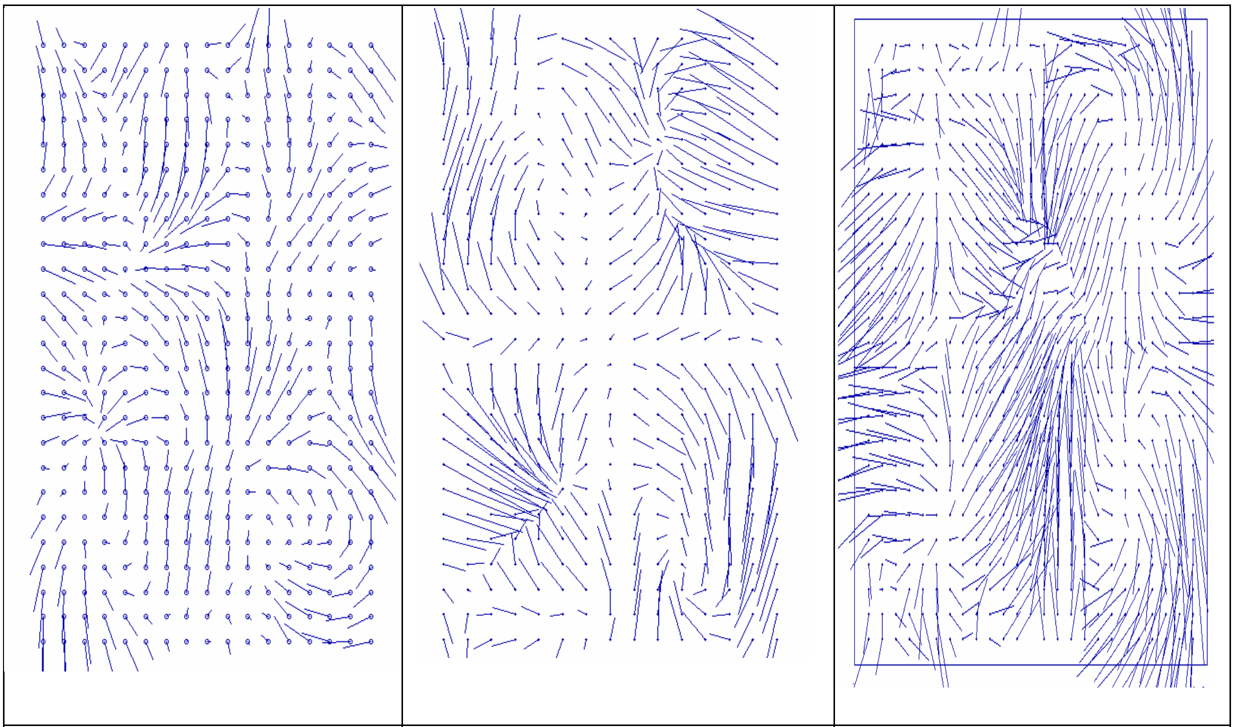


Figure 3: Systematic Image Errors of the DMC-block with 8cm GSD

By plotting the image residuals, further analysis is possible to show that the integration of sensor orientation overcomes some of the systematic errors produced from direct georeferencing. It can be seen that the sizes of the image residuals plotted for DMC with the integrated sensor orientation (Figure 3) are significantly decreased (please note that the scale of plotting is different in both diagrams). Also, they are comparable and point in random directions more than the image residuals from the direct georeferencing. This indicates the presence of systematic effects and that there are uncorrected errors in the direct georeferencing (Mikhail, 2001). Figure 4 shows that there is a marginal change in the sizes of image residuals plotted for the film camera with the integrated sensor orientation. So, it can be concluded that using in-flight GPS/IMU data within aerial triangulation solutions always improved results with large format digital DMC, and the benefits using in-flight GPS/IMU data within the aerial triangulation with film cameras were less. So, the integrated sensor orientation without ground control points and with the presence of automatic points can overcome these systematic errors produced from direct georeferencing.



Traditional AT	Integrated Sensor Orientaion	Direct Georeferencing

Figure 4: Systematic Image Errors of the RMK Top 15-block with 8cm GSD

CONCLUSIONS

Direct Georeferencing by in-flight GPS/IMU is used in two different concepts; direct georeferencing without using the aerial triangulation, and direct georeferencing using the aerial triangulation and only the automatically measured tie points (integrated sensor orientation). The accuracy of ground check points was investigated in this paper to study the quality of both concepts. The benefits of including in-flight GPS/IMU data within the aerial triangulation are far greater for the large format digital DMC data compared to imagery from film cameras. The precision of a typical image measurement for DMC is about 1.5μm, but the precision of a typical parallax measurement for RMK TOP 15 is about 4.5μm.

The results show the importance and the influence of GPS needed for the direct georeferencing with a DMC digital camera, and how this camera is sensitive to the accuracy of the data form GPS. DMC cameras can benefit from the higher quality of GPS data with a short baseline more than RMK film cameras.

REFERENCES

Casella, V. and Franzini, M. 2003. Definition of a Methodology for Local Reduction of Parallaxes in Directly Oriented Images. *Proceedings of ISPRS International Workshop*, WG I/5, September 2003, Castelldefels, Spain.

Cramer, M. 2003. Integrated GPS/Inertial and Digital Aerial Triangulation – Recent Test Results, In: D. Fritsch, ed., 'Photogrammetric Week '03, Herbert

Wichmann Verlag, Heidelberg, 161-172.

Cramer, M., Stallmann, D. and Halla, N. 2000. Direct Georeferencing Using GPS/Inertial Exterior Orientations for Photogrammetrics, 33 (B3/1): 189-206. Amsterdam.

Cramer, M. 2005. Digital Airborne Cameras-Status and Future. *ISPRS Hannover Workshop on High Resolution Earth Imaging for Geospatial Information Proceedings*, Volume XXXVI, Part I/W3, ISSN No. 1682-1777.

Cramer, M. and Haala, Norbert. 2009. DGPF Project: Evaluation of Digital Photogrammetric Aerial Based Imaging Systems-Overview and Results from the Pilot Centre. *ISPRS Hannover Workshop on High Resolution Earth Imaging for Geospatial Information Proceedings*, Volume XXXVIII-1-4-7_W5.

Gruber, M. and Ladstädler, R. 2006. Geometric Issues of the Digital Large Format Aerial Camera UltraCamD. *International Calibration and Orientation Workshop*, EuroCOW 2006. January 2006, Castelldefels, Spain. EuroSDR Commission I and ISPRS Working Group 1/3.

Jacobsen, K. 2009. DGPF-Projekt: Evaluierung digitaler photogrammetrischer Luftbildkamerasysteme-Auswerteteam Geometrie. DGPF, Tagungsband 2009.

Kruck, E. 2006. Simultaneous Calibration of Digital Aerial Survey Cameras. *International Calibration and Orientation Workshop*, EuroCOW 2006. January 2006, Castelldefels, Spain. EuroSDR Commission I and ISPRS Working Group 1/3.

Smith, M.J., Kokkas, N. and Qtaishat, K.S. 2007. Investigation into Self-Calibration Methods for the Vexcel UltraCam D Digital Aerial Camera. In: *ISPRS Hannover Workshop*, High Resolution Earth Imaging for Geospatial Information, 29 May - 1 June, 6 pp.

Smith, M.J., Qtaishat, K.S., Park, D.W.G. and Jamieson, A. 2006. IMU and Digital Aerial Camera Misalignment Calibration. In: EuroCOW 2006. *International Calibration and Orientation Workshop*, Castelldefels, Spain, 25-27 January 2006.

Smith, M.J., Qtaishat, K.S., Park, D.W.G. and Jamieson, A. 2005. Initial Results from the Vexcel UltraCam Digital Aerial Camera. In: Heipke, C., Jacobson, K. and Gerke, M., eds. *ISPRS Hannover Workshop:* High-Resolution Earth Imaging for Geospatial Information, Hannover, Germany. ISPRS, International Society for Photogrammetry and Remote Sensing, Volume XXXVI, Co I WGI/1, 6 pp.

Wegmann, H., Heipke, C. and Jacobsen, C. 2004. Direct Sensor Orientation Based on GPS Network Solution: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Istanbul, Turkey, Vol XXXV-B1, Commission I, 153-158.