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Using unmanned Aerial Vehicle (UAV) in Close Range Photogrammetry

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الملخص العربي

يعد الارجاع الجغرافي المباشر للصور الجوية الملتقطة بواسطة الطائرات ذاتية الحركة تقنية جديدة فعلي عكس الطرق التقليدية فانه لا تحتاج الي نقاط تحكم أرضية لذلك فانه يتميز بعده مميزات منها : السرعة في العمل الحقلي بالاضافة الي السرعة في التحليل وبالتالي قلة التكلفة.

تم في هذا البحث دراسة دقة استخدام النظام العالمي للملاحة بالاقمار الصناعية في الارجاع الجغرافي المباشر حيث اعطي دقة 0.029 متر افقيا و 0.026 متر رأسيا واعطت الطريقة التقليدية للارجاع الجغرافي باستخدام نقاط التحكم الارضية دقة 0.014 متر أفقيا و 0.013 متر راسيا.

ABSTRACT

Direct Geo-Referencing is a new technique in photogrammetry, especially in the aerial photogrammetry. Unlike the Aerial Triangulation “AT”, this method does not require Ground Control Points “GCPs”, to process aerial photographs into desired ground coordinates systems. Compared with the old method, this method has four main advantages: faster field work, faster data processing, simple workflow and less cost.

The current paper investigates the using GNSS system for providing the linear exterior orientation “EO” parameters by two techniques, real time kinematic “RTK” and virtual reference system “VRS”. The accuracy of the applied method is tested on topographic survey project in Switzerland. 182 captured images from approximately 85 m flight height, 18 Ground Check Point “GCP” determined by static GNSS. Horizontal accuracy is 0.029 meters for VRS case, 0.034 meters for RTK case and vertical accuracy is 0.026 meters for VRS case, 0.029 for RTK case.

Keywords: UAV photogrammetry; UAV imagery; Direct Geo-referencing; DG.

1. INTRODUCTION

Aerial photogrammetry is one of the most appropriate ways of data acquisition in producing large-scale topographical maps. Geo-referencing technique for Traditional aerial photogrammetry, called aerial triangulation “AT”, is depending mainly on Ground Control Points “GCPs”. This technique has many disadvantages and caused to many areas have not basic topographical maps due to lacking GCPs or inaccessible areas (Li, 2005).

Unlike AT, Direct Geo-referencing “DG” is the direct position and orientation measurements of the camera during capturing. Development in GNSS/INS technology made a great rebound in digital photogrammetry. GNSS records coordinate “X, Y, Z” and INS records orientation angles “w, φ, k” at the time of exposure. These measurements are integrated and form six parameters which are called Exterior Orientation “EO” parameters, that are used in collinearity equation for Geo-referencing (Cramer, 2000). The benefits of Direct Geo-referencing can be summarized as follows:

- Cost savings by elimination of needing GCPs in the field.
- Ability to generate remote locations maps.

- Real-time mapping for disaster response Applications.
- Eliminating or at least reducing side-lap requirements causing fewer flight lines per area.

In direct geo-referencing, EO parameters are computed through Kalman filter applied over the GNSS and INS observations. The errors of GNSS, time synchronization and Centre deviation between GNSS and camera may cause errors in linear EO parameters. In the same way, attitude measurement errors in INS may cause errors in angular EO parameters (Jacobsen, 2002). In DG, experiments appeared that the errors caused by angular parameters are larger than errors caused by linear parameters, and they are the most effect in DG errors (Cramer, 2002).

In the current paper, the accuracy of DG by using only linear EO parameters determined RTK and VRS techniques is investigated, the angular EO parameters are calculated in Structure from Motion “SFM” approach.

2. RESEARCH METHODOLOGY

2.1 Area of study

Our test area is in Switzerland, figure (1) shows the study area in google maps. In general, the test site covered approximately 0.827 km^2

Figure (1) the area study on the google map.

2.2 Data Acquisition

In 21/8/2014, flight data acquisition of a height approximately 85 meters above ground level has been performed using a fixed wing UAV eBee with wingspan 960 mm to photograph the test area, characteristics of the UAV are shown in table (1) and figure (2) shows the shapes of UAV and camera used.

This acquisition captured 182 full-color aerial images with 80 % overlap and 80 % side-lap which are sufficiently for processing by using the photogrammetric approach. 18-ground control and check points are distributed and determined by static post processing. In other side, the linear EO parameters for each photograph were determined by real time kinematic “RTK” and virtual reference system “VRS” techniques in World Geodetic System 1984 “WGS84”

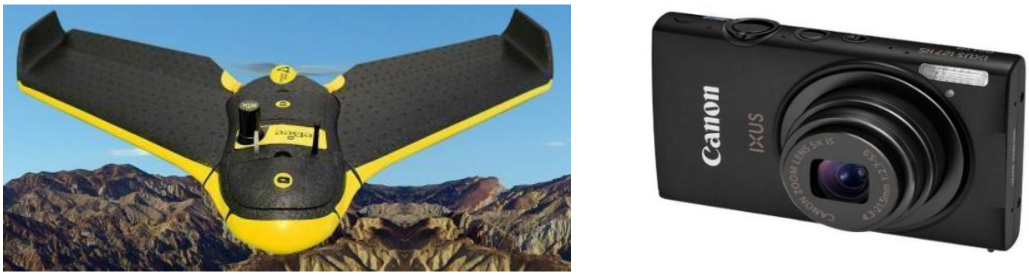

Figure (2) Fixed wing UAV and camera used

Table (1) characteristics of the eBee RTK UAV

Dimensions	55x45x25 cm
Weight	0.73 kg
Wing span	96 cm
Material	EPP foam and carbon
GNSS/RTK receiver	L1, L2, GPS, GLONASS
Max. flight time	40 minutes
Speed	40-90 km/hr.
Max. coverage “in one flight”	8 km2

2.3 Data processing

Agisoft Photo Scan is one of the most accurate photo processing software which is used to apply SFM approach. Firstly, it detects points in the images which are captured from different viewing and lighting sources then descript their points. Finally, the descriptors of the points are used for object reconstruction across the successive images (Agisoft, 2017). The linear EO parameters are read from Exchangeable Image File Format “EXIF”. The 3D model in an absolute coordinate has been created from pairs of images. The Agisoft photo scan has a good geometric accuracy, cost and ease of use (Gross. et al., 2015 & 2016).

3. RESULTS AND DISCUSSIONS

Direct Geo-referencing does not need any GCPs. So, all GCPs are changed to Independent Check Points “ICP” which used for to checking the accuracy of this method. RMSE are calculated by using SFM approach to measure GCPs coordinates “from models generated by linear EO parameter from GNSS” and compare them to original coordinates from static GNSS assumed as true value. RMSE is calculated for check points in the different between the UAV data and the reference data “static GNSS”.

3.1 Study the accuracy of Aerial Triangulation “AT”

18 ground points are measured by static GNSS. 10 points are used as GCPs and distributed in all area, the other 8 points are used as a check points as shown in Figure (3)

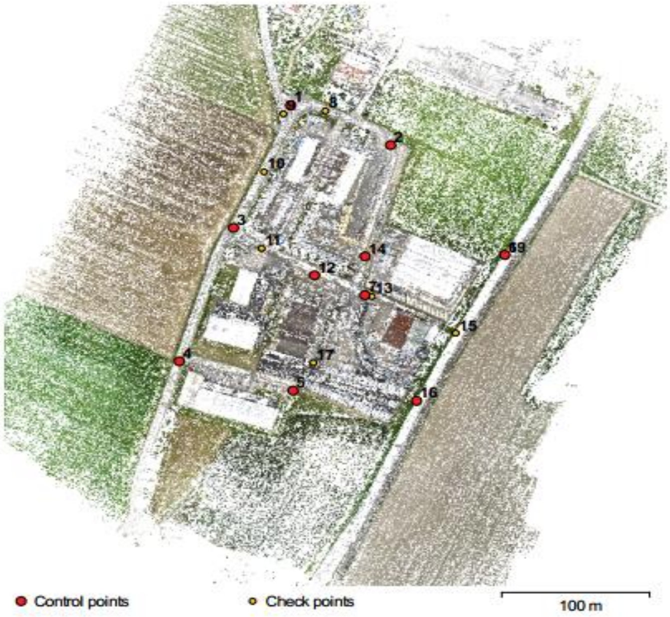

Figure (3) the GCPs and the check points locations

Accuracy of point clouds derived by AT process can be derived by comparing it with check points derived from static GNSS, as threshold values. The differences between the static GNSS check points and the related points in the point clouds are given in table (2).

As it is shown in table (2), one can easily conclude that the elevation and northing RMSE values are higher than Easting RMSE. Horizontal and Vertical errors have approximately the same RMSE. The maximum & the minimum values of horizontal error are 0.022 & 0.001 and for vertical error are 0.026 & 0.00002 m.

Table (2): Errors & RMSE of check points for AT process case.

Points	Easting error (m)	Northing error (m)	Horizontal error (m)	Vertical error (m)	Total error (m)
point8	-0.0004	0.007	0.007	-0.008	0.010
point9	0.005	0.021	0.022	0.00002	0.022
point10	0.0001	-0.008	0.008	0.026	0.029
point11	-0.010	-0.018	0.021	-0.006	0.022
point13	-0.004	-0.017	0.017	0.015	0.023
point15	0.001	-0.0008	0.001	0.013	0.013
point17	0.006	0.004	0.007	-0.013	0.015
point19	-0.0006	0.009	0.009	-0.0007	0.009
Total RMSE	0.006	0.013	0.014	0.013	0.019

3.2 Study the accuracy of the Direct Geo-referencing “DG”

The three linear EO parameters are determined by GNSS instead of calculated by AT. Two techniques of differential Global Navigational Satellite Systems are used, RTK and VRS.

Figure (4): check points locations

3.2.1 Study the accuracy of DG using RTK in determining linear EO parameters.

The linear EO parameters was determined by RTK, the angular EO was derived from AT. All 18-ground control points was used as a check points and are shown in Figure (4).

Accuracy of point clouds derived by RTK-DG process can be derived by comparing it with the check points derived from static GNSS, table (3). The maximum & the minimum values of horizontal error are 0.065 & 0.007 m. and for vertical error are 0.061 & 0.003 m.

Table (3): Errors & RMSE of check points for RTK-DG case

points	Easting error (m)	Northing error (m)	Horizontal error (m)	Vertical error (m)	Total error (m)
point1	0.0003	-0.037	0.037	-0.021	0.043
point2	-0.040	-0.016	0.043	-0.003	0.043
point3	0.019	0.001	0.019	0.005	0.019
point4	-0.030	0.056	0.064	-0.005	0.064
point5	0.024	0.009	0.026	-0.043	0.050
point6	-0.011	-0.0009	0.011	-0.016	0.020
point7	-0.063	0.014	0.065	-0.046	0.079
point8	-0.013	-0.023	0.026	-0.013	0.030
point9	0.005	-0.009	0.010	-0.013	0.016
point10	0.018	-0.011	0.021	0.008	0.023
point11	-0.009	-0.008	0.012	-0.014	0.019
point12	-0.024	0.029	0.038	-0.017	0.042
point13	-0.024	-0.008	0.025	-0.021	0.033
point14	0.006	0.003	0.007	-0.024	0.025
point15	-0.022	0.011	0.025	-0.041	0.048
point16	-0.038	0.024	0.045	-0.052	0.068
point17	-0.010	0.031	0.033	-0.061	0.069
point19	-0.027	0.011	0.029	-0.020	0.035
Total RMSE	0.026	0.022	0.034	0.029	0.045

3.2.2The accuracy of DG using VRS in determining linear EO parameters.

The linear EO parameters were determined by VRS, the angular EO was determined from AT. All 18-ground control points was used as a check points and are shown in Figure (4). Accuracy of VRS-DG process can be derived by compare it with check points derived from static GNSS, Table (4).

Table (4): Errors & RMSE of check points for VRS-DG case

points	Easting error (m)	Northing error (m)	Horizontal error (m)	Vertical error (m)	Total error (m)
point1	0.0064	-0.031	0.032	-0.029	0.043
point2	-0.028	-0.009	0.029	-0.011	0.031
point3	0.027	-0.002	0.027	0.009	0.029
point4	-0.010	0.051	0.052	0.009	0.052
point5	0.040	0.009	0.041	-0.028	0.050
point6	0.005	0.005	0.007	-0.016	0.017
point7	-0.047	0.017	0.050	-0.045	0.067
point8	-0.005	-0.016	0.017	-0.024	0.030
point9	0.010	-0.004	0.011	-0.018	0.022
point10	0.024	-0.012	0.027	0.012	0.029
point11	0.001	-0.010	0.010	-0.011	0.015
point12	-0.012	0.029	0.031	-0.007	0.032
point13	-0.008	-0.004	0.009	-0.021	0.022
point14	0.021	0.007	0.022	-0.026	0.034
point15	-0.005	0.016	0.017	-0.040	0.043
point16	-0.022	0.027	0.035	-0.038	0.051
point17	0.004	0.031	0.031	-0.044	0.054
point19	-0.011	0.017	0.020	-0.020	0.028
Total RMSE	0.020	0.021	0.029	0.026	0.039

As it is illustrated in table (4), it is easily to see that the maximum & the minimum absolute values of horizontal error are 0.052 & 0.007 m and for vertical error are 0.045 & 0.007 m.

3.3 Relation Between Accuracy of AT and RTK & VRS DG

For evaluating the point clouds extracted by RTK-DG, the point clouds extracted by VRS-DG against the point cloud extracted by AT, the total RMSE for eight check points are computed by the three methods. The results are given in table (5).

Table (5): Accuracy of AT and DG by linear EO parameters as determined by RTK and VRS techniques defined as Total points RMSE

Pts	Total points RMSE		
	AT by GCPs determined by Static GNSS	DG by linear OE parameters determined by	
		RTK	VRS
point8	0.010	0.030	0.030
point9	0.022	0.016	0.022
point10	0.029	0.023	0.029
point11	0.022	0.019	0.015
point13	0.023	0.033	0.022
point15	0.013	0.048	0.043
point17	0.015	0.069	0.054
point19	0.009	0.035	0.028
Total	0.019	0.045	0.039

As it is shown in table (5), the AT process has the highest accuracy, then VRS-DG and at finally the RTK-DG. This is compliant with the common accuracy of VRS and RTK.

4. CONCLUSIONS

The study has demonstrated that classical AT is more accurate than the UAV imagery DG. Direct Geo-referencing method has ability to provide products in good accuracy. Using VRS and RTK in determining the linear EO parameters in direct geo-referencing give a suitable accuracy enough to do the sequence processing. The accuracies achieved for VRS-DG and RTK-DG were 0.029 & 0.034 horizontal RMSE and 0.026 and 0.029 m for vertical RMSE. On the other side, the accuracy for AT horizontal RMSE was 0.014 m and 0.013 m vertical RMSE.

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