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Dear colleagues;

We are very glad to meet you with "International Journal of Environment and Geoinformatics" special issue which is a compilation of proceedings presented in "SELÇUK INTERNATIONAL SCIENTIFIC CONFERENCE ON APPLIED SCIENCES" held on 27-30 September in Antalya/Turkey.

Besides Turkish scientists, The Selçuk ISCAS 2016 brought together Russian, Ukrainian, Kazakhstan, Azerbaijani, Persian, Algerian, Nigerian, Netherlander, Scottish, Liberian, Philippines and Czech Republican scientists. Turkey General Directorate of Land Registry and Cadastre, Republic of Turkey Ministry of Food, Agriculture and Livestock Undersecretary, International Federal of Surveyors (FIG) and International Society for Photogrammetry and Remote Sensing (ISPRS) contribute to The Selçuk ISCAS 2016 at board of director's level.

The Selçuk International Scientific Conference on Applied Sciences (The Selçuk ISCAS 2016) held in Antalya on 27-30, September 2016. The Selçuk ISCAS 2016 is a candidate of one of the most important event in the scientific schedule and tenders a possibility for researchers and academicians who researches on applied sciences. You can find a first class programme of plenary speakers, technical sessions, exhibitions and social events in this book. You will be able to catch up with the developments in Geographical Information Sciences, Information Technology, Environmental Management and Resources, Sustainable Agriculture, Surveying, Photogrammetry and Remote Sensing, meet friends and experience the traditional and fascinating culture of TURKIYE. As an international conference in the field of geo-spatial information and remote sensing, The Selçuk ISCAS 2016 is devoted to promote the advancement of knowledge, research, development, education and training in Geographical Information Sciences, Information Technology, Environmental Management and Resources, Sustainable Agriculture, Surveying, Photogrammetry and Remote Sensing, their integration and applications, as to contribute to the well-being of humanity and the sustainability of the environment. The Conference of Selçuk ISCAS 2016 will provide us an opportunity to examine the challenges facing us, discuss how to support Future Earth with global geo-information, and formulate the future research agenda.

195 scientists from 13 countries attended to the symposium. 105 oral presentations, 40 fast oral presentations and 50 poster presentations are presented during the symposium. 145 oral and fast oral presentations take place in 24 technical sessions in two days. On the other hand, 5 invited speaker presentations held in the plenary session in the first day.

The conference is carried out with the support of the organizations as the Selçuk University, General Directorate of Land Registry and Cadastre, General Directorate Of Agricultural Reform, Turkish Cooperation and Development Agency (TIKA), International Federation of Surveyors (FIG) and International Society for Photogrammetry and Remote Sensing (ISPRS). In addition, the symposium is also supported by the commercial organizations of Paksoyteknik, Mescioğlu, Geogis, Körfez, Tümaş, 4B Ölçüm, GNSS Teknik, Arbiotek ve Anıt Hospital.

Best wishes.

Assoc. Prof. Dr. Ekrem Tuşat

Asist. Prof. Dr. Fatih Sarı

Prof. Dr. Hakan Karabörk

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Geometric Analysis of Digital Aerial Images

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Abstract

The data produced by photogrammetric methods have become used more effectively and efficiently to take place of digital aerial cameras to aerial film cameras. Digital aerial cameras have distinct properties according to imaging geometry, sensor numbers, the placement of camera cones and image recording techniques. Since 2000, many studies have been done upon the geometric analysis of the rapidly developing digital imaging system. Intergraph DMC and Vexcel Ultracam are among the most popular digital imaging systems in this area. These cameras are large-format digital aerial camera systems.

The purpose of the present study was to investigate the geometric performance of DMCII-250e and Vexcel UltraCamX large-format digital aerial camera systems. The test flights were performed in Bursa province. Two different image blocks which are 10 cm GSD and 30 cm GSD were acquired at different flight altitudes. The image measurements for aerial triangulation were performed by Mescioglu Engineering Inc. The images were processed with Match-AT software. It has been compared the residuals of coordinates and RMS of ground control points and check points triangulated image blocks.

Keywords: Analysis, Aerial Cameras Aerial Triangulation, Check Points, GCP

Introduction

The data produced by photogrammetric methods have become used more effectively and efficiently to take place of digital aerial cameras to aerial analog photogrammetric cameras. The first aerial photographs that were captured by using a kite or balloon are now replaced by digital images captured with large-format digital cameras. The discussion if digital or analog aerial cameras should be used came to an end (Doğan et al., 1998). The biggest advantage of the digital aerial cameras is the large-format panchromatic integrated images depending on the location of the camera cones. Therefore wider areas can be photographed in higher resolution and in a short space of time. The end product obtained from the aerial triangulation is that of the georeferenced digital images and three-dimensional coordinate data (Cramer, M., et.al. 2000, Yuan, 2008, Scaloud, J., 2008).

Since 2000, many studies have been done upon the geometric analysis of the rapidly developing digital imaging system. Especially, Intergraph DMC and Vexcel UltraCam which are to be members of large format digital aerial frame camera family are the most popular sensors for analysing aerial images.

In this study to evaluate geometric accuracy of different aerial blocks the flights were carried out with the DMCII-250e and UltraCamX digital aerial frame camera. According to the adjustment results of each block, it has been compared the residual of coordinates and RMS of ground control points and check points.

Materials: Test Site

Test site is in Bursa which is the province of Turkey. The locations of blocks in test site have been given in Figure 1 and Figure 2. Figure 1 represents with 30 cm GSD block and the block size is approximately 9000 km2, other is 10 cm GSD block and 88 km2. The images with 30 cm GSD were collected the flying attitude above ground level 6000 m using Vexcel UltraCamX digital aerial camera. The images with 10 cm GSD were collected the flying attitude above ground level 2000 m using Z/I DMCII-250e digital camera. All flights were conducted on the east-west direction.

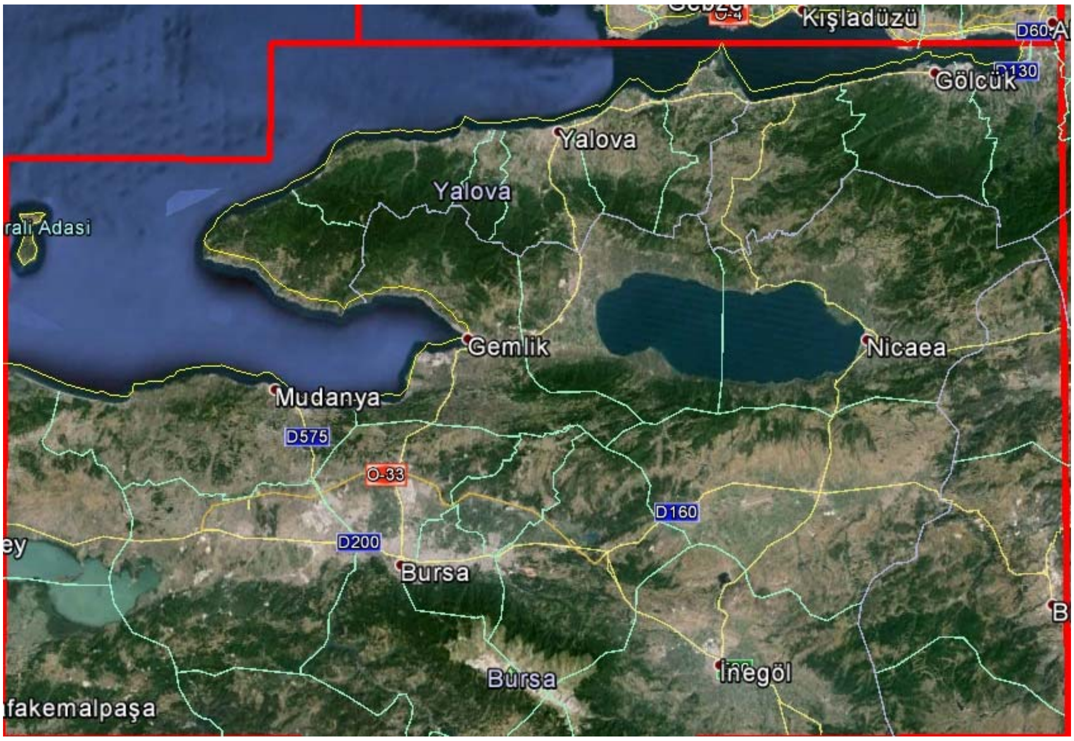

Figure 1. The block of 30 cm GSD

Figure 2. The block of 10 cm GSD

Figure 3 and Figure 4 illustrate the location and distribution of the ground control points within the blocks. To correct of possible geodetic errors in aerial triangulation, the weight of ground control points has been accepted equal. The weight of ground control points is x/y=0.03 z=0.05 unit.

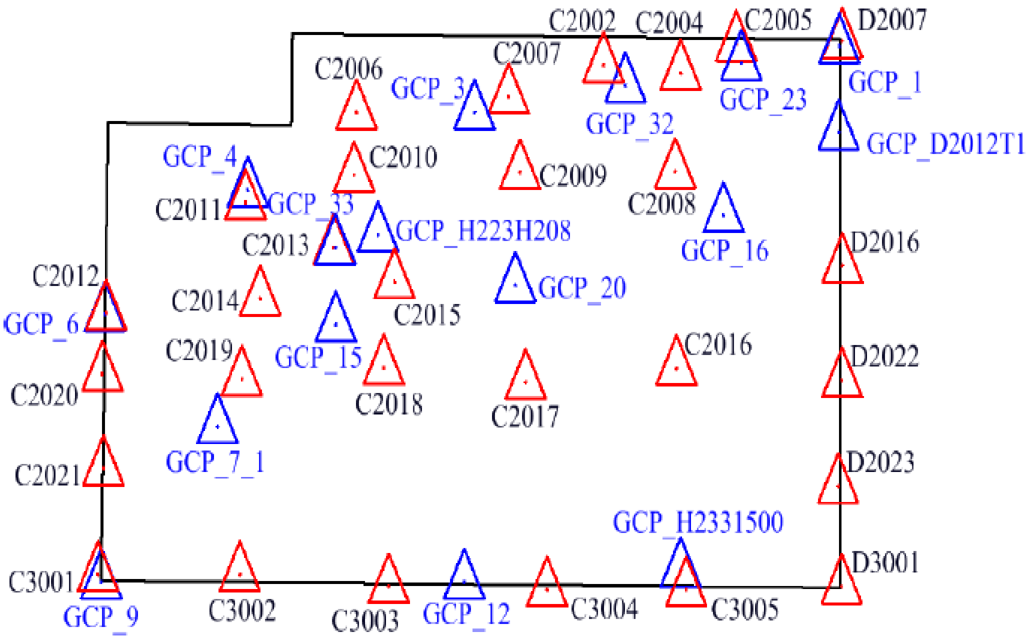

Figure 3. The distribution of GCPs in the 30 cm GSD block

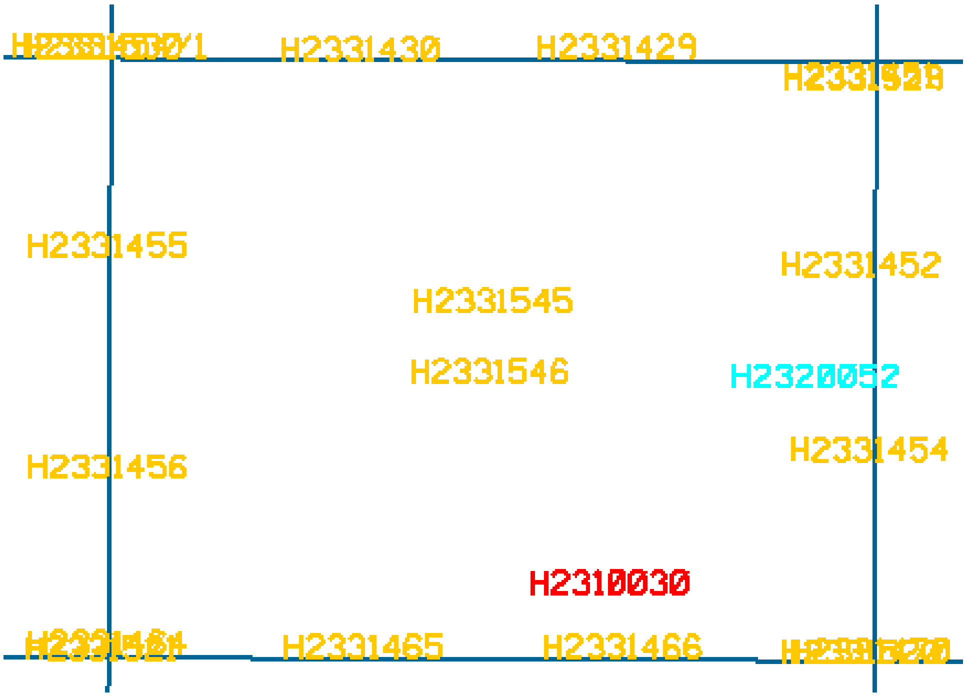

Figure 4. The distribution of GCPs in the 10 cm GSD block

DMCII-250e

In the recent years, the ability of large format digital frame cameras have been developed together with innovations CCD imaging technology. DMCII-140, DMCII-230, DMCII-250 and newly DMC III are introduced Z/I imaging and Leica Geosystems., DMCII-250e version of the DMCII camera family has been used in this study. DMCII-250e is high performance camera system. It has five nadir-looking camera heads four multispectral cameras for red, green, blue and near infrared. DMCII-250e large format digital frame camera includes a 250 mpixel resolution of 16768*14016 with 5.6 micron pixel size, 112 mm focal lenght, b/h ratio of 0.29, radiometric resolution of 14 bits and exposure period of 1.7 seconds.

Vexcel ULTRACAMX

UltraCamX large format digital aerial camera is manufactured by Vexcel Imaging company in 2006. The sensor head is designed as a digital frame camera. UltraCamX consists of eight independent camera cones, four cones of them contributing to the large format panchromatic image and other four cones contributing to the multi spectral image (Gruber M., et al 2008). The technical data and specification of the UltraCamX aerial camera used in this study are given in Table 1.

Methods: Digital Aerial Triangulation

The digital aerial triangulation is divided into various processing step;

- Data preparation
- Automatic data import and generation of image pyramid level
- Automatic interior orientation
- Automatic aerial triangulation point measurement
- GPS supported bundle block adjustment
- Bundle adjustment
- Quality control

The most important processing steps in an extensive GNNS/INS based aero triangulation study are the preparation of flight plans. This procedure, originally starting with the block planning, includes many aspects that need to be taken into consideration. The aspects that are taken into consideration while scheduling an aero-triangulation flight plan include the topographic structure of the region, the geometrical properties of the project site, the photogrammetric block structure, the frame size of the camera to be used, ground sampling distance (GSD), base length, forward and side lap overlap ratios.

Table 1. Technical data and specifications of the Vexcel UltraCamX aerial camera.

Digital Camera	ULTRACAMX
Panchromatic Channel	4 camera heads
Image size in pixel (cross and along track)	14430*9420 pixel
Physical pixel size	7.2 micron
Physical image format	103.9 mm*67.8 mm
Focal length	100.50 mm
Multispectral Channel	4 camera heads
Image size in pixel (cross and along track)	4810*3140 pixel
Physical pixel size	21.6 micron
Physical image format	67.8 mm*103.9 mm
Focal length	100.5 mm
Radiometric resolution	> 12 bit /channel

All of processing steps can be made seamlessly; a powerful photogrammetric workstation, the commercial triangulation software and an experienced operator are required.

In order to ensure 1/10-pixel accuracy in tie points, automatic image correlation module based on the least squares approach has been used for each stereo model. The tie points which are exceed 8 micrometer are cleaned. After this process step, the digital aerial triangulations were undertaken with commercial triangulation software package MATCH-AT from Inpho. The most common analysis of aerial triangulation based-GPS is the bundle block adjustment (Yuan, 2009). The images were triangulated with bundle adjustment mathematical model procedure. The bundle adjustment was applied by self-calibration with set of 12-additional parameters.

The block of 30 cm GSD UltraCamX contains 4500 images; other test block contains 250 images.

The accuracy of a block is associated with the number of ground control points and the accuracy of such points. In this study, 30 ground control points and 15 check points were used for 30 cm GSD UltraCamX block; 18 ground control points and 5 check points were used for 10 cm GSD DMCII-250e block.

Table 2. The accuracy of the ground control points of 30 cm GSD bundle block adjustment in AT

RMS and Max. Residuals of Ground Control Points for 30 cm GSD Block												
Known coordinates of ground control points				Measured coordinates at block adjustment			Max. Residuals of Ground Control Points			RMSE		
Name of Points	Easting	Northing	Height	Easting	Northing	Height	ΔX	ΔY	ΔH	$ΔX^2$	$ΔY^2$	$ΔH^2$
C2002	458905.330	4508835.151	2.189	458905.480	4508835.310	2.030	-0.15	-0.16	0.16	0.02	0.03	0.03
C2004	472239.632	4507669.944	1.529	472239.458	4507669.810	1.750	0.17	0.13	-0.22	0.03	0.02	0.05
C2005	481901.668	4512011.889	1.769	481901.370	4512011.800	1.260	0.30	0.09	0.51	0.09	0.01	0.26
C2006	416109.258	4501665.632	30.717	416109.340	4501665.750	30.530	-0.08	-0.12	0.19	0.01	0.01	0.03
C2007	442451.743	4504072.306	2.000	442451.370	4504072.320	1.370	0.37	-0.01	0.63	0.14	0.00	0.40
C2008	471292.276	4492752.195	712.897	471292.300	4492752.090	713.000	-0.02	0.11	-0.10	0.00	0.01	0.01
C2009	444419.059	4492611.926	689.952	444419.160	4492611.790	689.880	-0.10	0.14	0.07	0.01	0.02	0.01
C2010	415695.431	4492225.643	723.215	415695.390	4492225.450	723.480	0.04	0.19	-0.26	0.00	0.04	0.07
C2011	396912.557	4488032.747	54.810	396912.810	4488032.500	54.990	-0.25	0.25	-0.18	0.06	0.06	0.03
C2012	372730.210	4471347.688	5.135	372730.490	4471347.860	5.550	-0.28	-0.17	-0.42	0.08	0.03	0.17
C2013	412163.964	4481273.475	1.399	412163.964	4481273.475	1.525	0.00	0.00	-0.13	0.00	0.00	0.02
C2014	399400.789	4473469.391	65.955	399400.670	4473469.540	65.600	0.12	-0.15	0.36	0.01	0.02	0.13
C2015	422663.509	4476045.631	1.632	422663.340	4476045.590	1.270	0.17	0.04	0.36	0.03	0.00	0.13
C2016	471502.679	4462907.433	281.251	471502.440	4462907.350	281.630	0.24	0.08	-0.38	0.06	0.01	0.14
C2017	445395.221	4460839.642	592.450	445394.860	4460839.310	592.858	0.36	0.33	-0.41	0.13	0.11	0.17
C2018	420808.051	4463034.798	172.491	420807.600	4463034.500	172.780	0.45	0.30	-0.29	0.20	0.09	0.08
C2019	396230.250	4461319.340	74.654	396230.250	4461319.340	74.654	0.00	0.00	0.00	0.00	0.00	0.00
C2020	372082.805	4462076.272	112.781	372082.790	4462076.440	113.230	0.02	-0.17	-0.45	0.00	0.03	0.20
C2021	372276.886	4447751.370	5.507	372277.020	4447751.510	5.206	-0.13	-0.14	0.30	0.02	0.02	0.09
C3001	371907.397	4430609.165	141.746	371907.530	4430609.070	141.553	-0.13	0.09	0.19	0.02	0.01	0.04
C3002	395897.567	4431683.154	341.277	395897.850	4431683.070	341.258	-0.28	0.08	0.02	0.08	0.01	0.00
C3003	421664.057	4429875.469	797.746	421664.250	4429875.570	797.180	-0.19	-0.10	0.57	0.04	0.01	0.32
C3004	449073.211	4429394.933	1074.226	449073.020	4429394.760	1073.680	0.19	0.17	0.55	0.04	0.03	0.30
C3005	473189.970	4429414.034	891.412	473190.100	4429413.990	891.253	-0.13	0.04	0.16	0.02	0.00	0.03
D2007	500263.666	4512496.046	7.564	500263.860	4512496.160	7.256	-0.19	-0.11	0.31	0.04	0.01	0.09
D2012T1	499648.359	4498619.965	749.621	499648.400	4498620.100	750.160	-0.04	-0.13	-0.54	0.00	0.02	0.29
D2016	500274.566	4478437.448	379.386	500274.300	4478437.570	379.080	0.27	-0.12	0.31	0.07	0.01	0.09
D2022	500233.782	4461097.701	243.463	500233.520	4461097.360	243.760	0.26	0.34	-0.30	0.07	0.12	0.09
D2023	499545.463	4445091.776	407.144	499545.490	4445091.450	407.008	-0.03	0.33	0.14	0.00	0.11	0.02
D3001	500178.151	4429854.473	693.703	500178.250	4429854.460	693.780	-0.10	0.01	-0.08	0.01	0.00	0.01
The max. residuals define the different between the results of AT and the known coordinates of gorund control points										$ΕΔX^2$	$ΕΔX^2$	$ΕΔH^2$
										1.27	0.83	3.29
										RMSE X $\sqrt{Ε\|ΔX\|^2/(n-1)}$	RMSE Y $\sqrt{Ε\|ΔY\|^2/(n-1)}$	RMSE H $\sqrt{Ε\|ΔH\|^2/(n-1)}$
										0.17	0.14	0.27

Results and Analysıs

For analyzing of the triangulated blocks were selected the check points and the ground control points where the differences between measured coordinates in terrain and photogrammetric adjusted coordinates. Table 2, 3, 4 and 5 shows the maximum residuals and RMS of ground control points and check points triangulated image blocks.

Table 3. The accuracy of the check points of 30 cm GSD bundle block adjustment in AT.

RMS and Max. Residuals of Check Points for 30 cm GSD Block												
Known coordinates of check points				Measured coordinates at block adjustment			Max. Residuals of Check Points			RMSE		
Name of Points	Easting	Northing	Height	Easting	Northing	Height	ΔX	ΔY	ΔH	ΔX^2	ΔY^2	ΔH^2
1	499765.393	4511691.754	8.703	499765.530	4511691.780	8.340	-0.137	-0.026	0.363	0.02	0.00	0.13
3	436560.570	4501645.424	66.905	436560.780	4501645.430	66.685	-0.210	-0.006	0.220	0.04	0.00	0.05
4	397282.362	4489983.282	32.474	397282.370	4489983.580	32.230	-0.008	-0.298	0.244	0.00	0.09	0.06
6	372526.590	4471200.815	27.838	372526.150	4471200.720	28.000	0.440	0.095	-0.162	0.19	0.01	0.03
7_1	392068.096	4454127.660	51.826	392068.320	4454128.110	51.420	-0.224	-0.450	0.406	0.05	0.20	0.16
9	371318.446	4431692.313	231.391	371318.690	4431692.670	230.960	-0.244	-0.357	0.431	0.06	0.13	0.19
12	434803.152	4430573.266	1221.802	434803.310	4430572.790	1221.730	-0.158	0.476	0.072	0.02	0.23	0.01
15	412530.418	4469520.524	10.194	412529.980	4469520.700	10.270	0.438	-0.176	-0.076	0.19	0.03	0.01
16	479699.734	4486089.261	537.707	479699.450	4486089.340	537.610	0.284	-0.079	0.097	0.08	0.01	0.01
20	443601.105	4475538.754	206.325	443601.200	4475539.380	205.970	-0.095	-0.627	0.355	0.01	0.39	0.13
23	482757.214	4509120.412	70.035	482757.660	4509120.160	70.190	-0.446	0.252	-0.155	0.20	0.06	0.02
32	462693.110	4505771.487	2.051	462693.750	4505771.310	1.720	-0.640	0.177	0.331	0.41	0.03	0.11
33	412478.416	4481237.312	1.998	412478.040	4481237.240	1.972	0.376	0.072	0.026	0.14	0.01	0.00
H2331500	472230.894	4432313.441	350.420	472230.830	4432313.730	350.480	0.064	-0.289	-0.060	0.00	0.08	0.00
H223H208	419825.741	4483146.418	1.179	419825.440	4483146.470	1.990	0.301	-0.052	-0.811	0.09	0.00	0.66
The max. residuals define the different between the results of AT and the known coordinates of check points										$\varepsilon\Delta X^2$	$\varepsilon\Delta X^2$	$\varepsilon\Delta H^2$
										3.11	2.49	5.62
										RMSE X $\sqrt{\varepsilon\|\Delta X\|^2/(n-1)}$	RMSE Y $\sqrt{\varepsilon\|\Delta Y\|^2/(n-1)}$	RMSE H $\sqrt{\varepsilon\|\Delta H\|^2/(n-1)}$
										0.27	0.24	0.36

Table 4. The accuracy of the ground control points of 10 cm GSD bundle block adjustment in AT

RMS and Max. Residuals of Ground Control Points for 10 cm GSD Block												
Known coordinates of ground control points				Measured coordinates at block adjustment			Max. Residuals of Ground Control Points			RMSE		
Name of Points	Easting	Northing	Height	Easting	Northing	Height	ΔX	ΔY	ΔH	ΔX^2	ΔY^2	ΔH^2
H2331470	472333.56	4454553.64	376.01	472333.54	4454553.65	376.02	0.02	-0.01	-0.01	0.000	0.000	0.000
H2331520	472197.92	4454540.19	391.35	472197.93	4454540.18	391.29	-0.01	0.01	0.06	0.000	0.000	0.003
H2331466	468879.91	4454611.25	254.67	468879.90	4454611.25	254.70	0.01	0.00	-0.03	0.000	0.000	0.001
H2331521	461623.07	4454587.58	236.71	461623.11	4454587.62	236.73	-0.04	-0.05	-0.02	0.002	0.002	0.000
H2331529	472224.34	4462517.42	298.46	472224.35	4462517.41	298.47	-0.01	0.01	-0.02	0.000	0.000	0.000
H2331451	472162.24	4462556.66	294.41	472162.25	4462556.65	294.42	-0.01	0.01	-0.01	0.000	0.000	0.000
H2331429	468801.65	4462945.30	337.03	468801.69	4462945.30	337.09	-0.04	-0.01	-0.06	0.002	0.000	0.003
H2331430	465247.21	4462915.45	277.85	465247.31	4462915.39	277.93	-0.10	0.06	-0.08	0.010	0.004	0.007
H2331530	461655.99	4462962.33	288.19	461656.09	4462962.33	288.24	-0.10	-0.01	-0.05	0.010	0.000	0.003
H2331455	461736.62	4460186.98	232.56	461736.62	4460187.02	232.62	0.01	-0.05	-0.06	0.000	0.002	0.004
H2331452	472197.90	4459929.21	234.32	472197.93	4459929.20	234.36	-0.04	0.01	-0.05	0.001	0.000	0.002
H2331545	467087.16	4459419.28	228.01	467087.14	4459419.27	228.14	0.02	0.01	-0.13	0.000	0.000	0.016
H2331546	467037.83	4458439.20	226.87	467037.78	4458439.20	226.97	0.04	0.01	-0.10	0.002	0.000	0.009
H2320052	471571.86	4458376.23	222.67	471571.87	4458376.29	222.66	-0.01	-0.07	0.01	0.000	0.004	0.000
H2331456	461734.22	4457118.06	232.77	461734.21	4457118.06	232.79	0.01	0.00	-0.02	0.000	0.000	0.000
H2331454	472330.89	4457354.67	222.12	472330.90	4457354.71	222.20	-0.01	-0.04	-0.08	0.000	0.002	0.006
H231H003	468693.21	4455502.07	242.56	468693.15	4455502.07	242.58	0.06	0.00	-0.02	0.004	0.000	0.000
H2331465	465289.87	4454611.11	232.41	465289.89	4454611.14	232.39	-0.02	-0.04	0.02	0.001	0.001	0.001
The max. residuals define the different between the results of AT and the known coordinates of gorund control points										$\varepsilon\Delta X^2$	$\varepsilon\Delta X^2$	$\varepsilon\Delta H^2$
										0.032	0.016	0.056
										RMSE X $\sqrt{\varepsilon\|\Delta X\|^2/(n-1)}$	RMSE Y $\sqrt{\varepsilon\|\Delta Y\|^2/(n-1)}$	RMSE H $\sqrt{\varepsilon\|\Delta H\|^2/(n-1)}$
										0.038	0.027	0.051

Table 5. The accuracy of the check points of 10 cm GSD bundle block adjustment in AT.

RMS and Max. Residuals of Check Points for 10 cm GSD Block												
Known coordinates of check points				Measured coordinates at block adjustmen			Max. Residuals of Check Points			RMSE		
Name of Points	Easting	Northing	Height	Easting	Northing	Height	ΔX	ΔY	ΔH	ΔX^2	ΔY^2	ΔH^2
D3	470151.81	4460763.66	237.24	470151.83	4460763.70	237.27	-0.02	-0.04	-0.03	0.001	0.001	0.001
D4	470165.09	4460659.86	236.24	470165.08	4460659.95	236.36	0.01	-0.09	-0.12	0.000	0.008	0.015
D2	463577.04	4460353.92	232.97	463577.12	4460353.93	233.12	-0.09	-0.01	-0.16	0.008	0.000	0.024
D6	464155.13	4456800.68	232.53	464155.15	4456800.68	232.59	-0.02	-0.01	-0.06	0.000	0.000	0.003
D8	469542.63	4457050.22	225.43	469542.64	4457050.21	225.45	-0.01	0.01	-0.02	0.000	0.000	0.000
The max. residuals define the different between the results of AT and the known coordinates of check points										$\varepsilon\Delta X^2$	$\varepsilon\Delta X^2$	$\varepsilon\Delta H^2$
										0.009	0.009	0.044
										RMSE X $\sqrt{\varepsilon\|\Delta X\|^2/(n-1)}$	RMSE Y $\sqrt{\varepsilon\|\Delta Y\|^2/(n-1)}$	RMSE H $\sqrt{\varepsilon\|\Delta H\|^2/(n-1)}$
										0.020	0.020	0.045

Conclusion

The digital large format aerial cameras are becoming increasingly important systems due to growing demands to digital orthophoto, digital surface models and digital terrain models.
Within this study the geometrical performance analysis of DMCII-250e and UltraCamX were analyzed in different blocks. It has been compared the residuals of coordinates and RMS of ground control points and check points triangulated image blocks.

Summarizing, the results obtained in the present study indicate that;

- In 30 cm GSD Block, RMSE of the ground control point is smaller than 1.0 pixel in planimetry and height, RMSE of check points is smaller than 1.0 pixel in planimetry and 1.2 pixel in height.

- In 10 cm GSD Block, RMSE of the ground control point is smaller than 1.0 pixel in planimetry and height, RMSE of check points is smaller than 1.0 pixel in planimetry and height.

The results obtained in this work are suitable for ASPRS Standard and for producing Turkey National Standard topographic maps. It was concluded that the 1/5000 scale digital topographic maps can be generated from 30 cm GSD images and the 1/1000 scale digital topographic maps can be generated from 10 cm GSD images.

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