Aerial Triangulation Test Project with UAS Technology

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***Abstract*— the paper deals with the optimization of the aerial triangulation based on UAS images. The images were taken with a DJI Phantom 3 Advanced quadrocopter and they were measured in Photomod UAS Lite ver. 6. The bundle adjustment was carried out twice, first in Photomod Solver and later in BINGO ver. 6.8. During the adjustment 14 ground control points were used and 34 points were calculated as new points. Using these new points we could compare the coordinates to the coordinates received from the high-precision field surveying measurements. From the coordinate differences the calculated RMS errors of horizontal coordinates are below the pixel size on the ground horizontally and vertically as well. The final results showed us that a non-metric camera at low flight height with a quadrocopter can be used effectively and accurately at aerial surveys of relatively small areas.**

***Keywords*— UAS, aerial triangulation, bundle adjustment, error assessment**

I. Introduction

For testing, some large scale aerial photos were used taken at a relative height of 116 m. The test field was marked with 49 signs distributed by a grid. The images were taken with a DJI Phantom 3 Advanced quadrocopter having a 12 Mpixel camera and they were measured in Photomod UAS Lite ver. 6. and the bundle block adjustment of 16 images was done initially in Photomod. After checking the residuals and RMS values a second bundle adjustment was carried out in BINGO ver. 6.8. During the final block adjustment the camera calibration and the systematic image distortion compensation was calculated as well. During the adjustment 14 ground control points were used and 34 points were calculated as new points. Using these new points we could compare the coordinates to the coordinates received from the high-precision field surveying measurements. From the coordinate differences the calculated RMS errors of horizontal coordinates are around 2 centimeters and the RMS error of vertical coordinates is 3.2 centimeters. The pixel size on the ground was 5 cm, which means the RMS errors corresponds to 0.4 pixel in X, Y and to 0.6 pixels vertically.

II. Test Area

For testing, we used an area of 200x200 m near Szekesfehervar close to village Iszakszentgyorgy. The size of the point marks was 50x50 centimetres (see Fig. 1 and Fig. 2). On Fg 1 the control points are indicated with red circles.

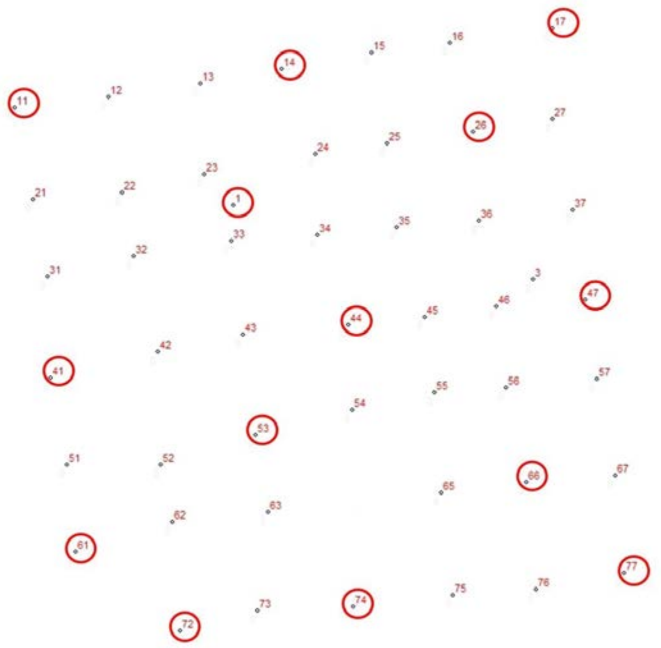

Fig. 1 Coordinate system for relative orientation

Fig. 2 Point mark on the test area

III. 3. Phantom DJI 3 Advanced

The DJI (official name is Dà-Jiāng Innovations Science and Technology Co., Ltd) company manufactures unmanned aerial vehicles for aerial photography and for video purposes. The company headquarter is located in the industrial heart of

China in Shenzen. One of the leading economic journal of the world chose DJI for the leading company of civil drone industry in 2015. One of the most popular product of the company is the Phantom series quadcopters.

A. Technical Data

Our Faculty has a DJI Phantom 3 Advanced aircraft (Fig. 3.). This UAV is available from the middle of 2015 and has more new features e.g. safer indoor use. The whole equipment is 1280 grams and its maximum ascend speed is 5 km/h and maximum horizontal speed is around 45 km/h. The UAV is equipped with GPS/Glonass receiver and has a precise 3 axis gimbal for good performance. The maximum operating range is more than 2 kilometres and the 4480 mAh LiPo battery operates for 22 minutes per charges.

Autopilot and 'GO HOME' function is available at any time or at less than 20 percent battery operation time. During flight an almost real time video (latency is 220 ms) is available thanks to DJI's Lightbridge technology.

The on board camera is a Sony EXMOR 1/2.3" camera which has 12.4 million effective pixels (the total pixels are 12.76 millions). The lens has a FOV of 94° with 20 mm focal length (35 mm format equivalent) and with f/2.8. The ISO range is 100-3200 for video recording and 100-1600 for photos. The shutter speed varies between 8 and 1/8000 seconds.

A new technology helps to fly safe indoor as the UAV is equipped with ultrasound sensors. The still photography modes contains single shot, burst shooting (3/5/7 shots), auto exposure and time lapse. The video mode contains 2.7K, FHD and HD.

The DJI GO application is available for IOS and Android. We use this device with Samsung Galaxy3 8" tablet.

Fig. 3 DJI Phantom 3 Advanced UAS (source: DJI.com)

B. Mission Planning

The images were taken on September 7, 2016. We managed to get 16 images organized in 4 strips with relative flight height of 116 m and with the following image numbers (see also Fig. 4):

Strip 1: 14, 15, 16, 17;
Strip 2: 18, 19, 20, 21;
Strip 3: 22, 23, 24, 25;
Strip 4r: 26, 27, 28, 29.

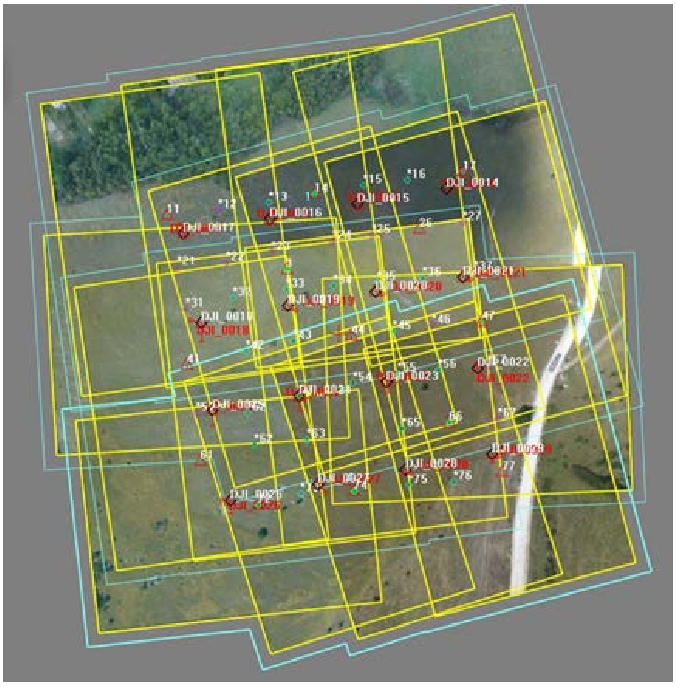

Fig. 4 Block of images

We carried out the flight in autopilot mode using the UgCS (Universal Ground Control Station) software application. In UgCS we managed to setup a 70 % overlap between the images and 60% overlap between the strips (Fig. 5). The whole autopilot flight procedure had the following steps:

1. Plan the flight in desktop application.
2. Go to the test area.
2. Switch on the remote controller and then the drone.
3. Connect the remote controller and the tablet by wire.
4. Switch on the tablet and start the UgCS application.
5. Join the tablet and the laptop into the same Wi-Fi network.
6. Launch the UgCS application on the laptop and wait for recognition of the drone.
7. Switch to "P" mode the remote controller and take off (approximately at 1m height) and then switch to "F" mode.
8. Choose the flight plan and upload it to the tablet.
9. Launch the "Auto Mode".
10. At the end of the mission: "Return Home".

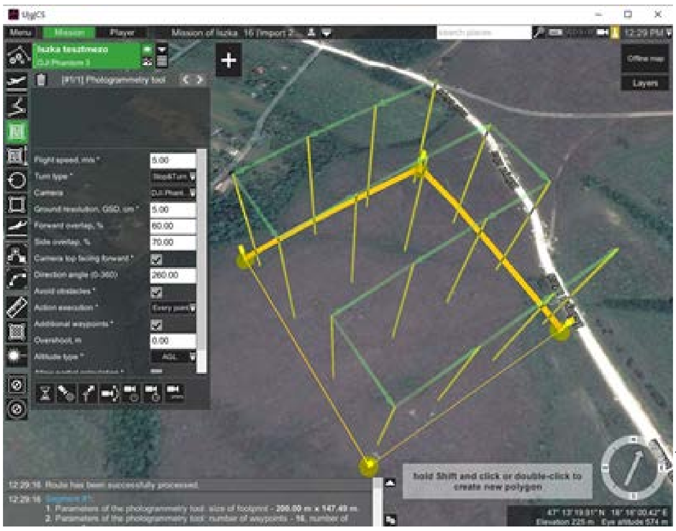

Fig. 5 Mission planning in UgCS

IV. 4. AERIAL TRIANGULATION

C. Orientation and Measurement in Photomod

After pre-processing and improving the bright and contrast on images we started the orientation process of 11 images in Photomod UAS Lite v6. [2]. The interior orientation meant simply to key in the camera parameters.

The next step was to measure the ground control points (GCPs) and new points on each stereo-pair (Fig 5).

After the measurement of all points we could initiate the relative orientation for the block and checking the vertical parallaxes on each stereo-pair and triplets we managed to prepare the whole block for the aerial triangulation (Fig. 6).

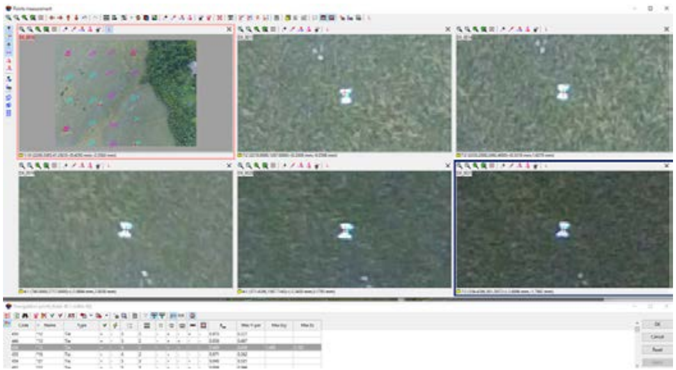

Fig. 5 Measuring of control and tie points

Strip: 1

	Stereopair	Number of points	Vertical parallax, pix.			Discrepancy of kappa angle, gon	Distribution uniformity	
			RMS	Mean abs.	Max			
	DJI_0017—DJI_0016	10	0.213	0.187	0.395	-0.340741	Non-uniform	
	DJI_0016—DJI_0015	12	0.412	0.362	0.766	0.692129	Non-uniform	
	DJI_0015—DJI_0014	8	0.435	0.354	0.833	-2.047492	Non-uniform	

	Triplet	Number of points	Tie residuals, pix.					
			RMS		Mean abs.		Max	
			E_{xy}	E_z	E_{xy}	E_z	E_{xy}	E_z
	DJI_0017—DJI_0016—DJI_0015	2	0.224	0.674	0.224	0.672	0.243	0.710
	DJI_0016—DJI_0015—DJI_0014	3	0.236	1.093	0.223	1.022	0.329	1.567

Fig. 6 Relative orientation results for the sirst strip

D. Aerial triangulation

Finishing the measurement we could build the block scheme and we could start the block adjustment procedure in Photomod Solver [3], (Fig. 7.).

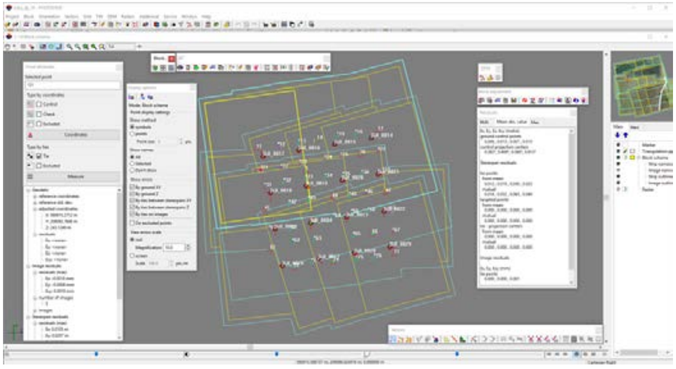

Fig. 7 Results in Photomode Solver

In order to have better results we decided to repeat the bundle block adjustment using the BINGO v6.8 software. The initial values of the exterior orientation elements were taken from Photomod Solver, so we expected only small corrections. Before running the BINGO we decided to add the camera calibration process to the adjustment and referring to the BINGO manual [1], we added 17 additional parameters to correct the systematic image errors. The final report of results is shown on Fig. 8. The sigma0 is 0.79 microns, which is acceptable. Since the adjustment procedure is optimised to the ground control points, the RMS errors of GCPs are extremely good, in X, Y it is only 3 mm and in Z it is 1 mm.

On Fig. 9 we can observe the distribution of error ellipses on new points printed out from the Bingo error assessment module.

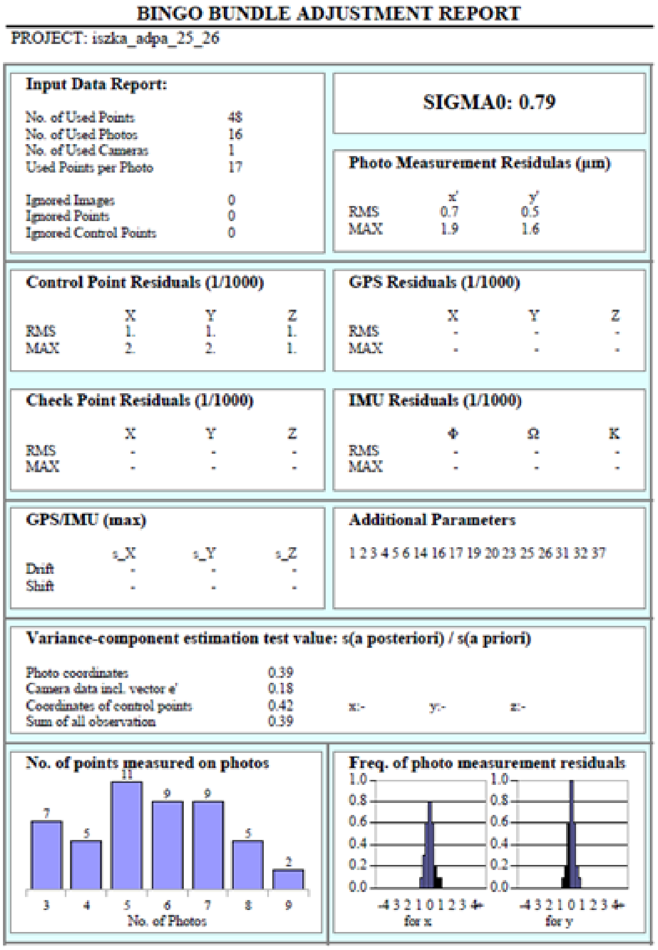

Fig. 8 BINGO adjustment report page

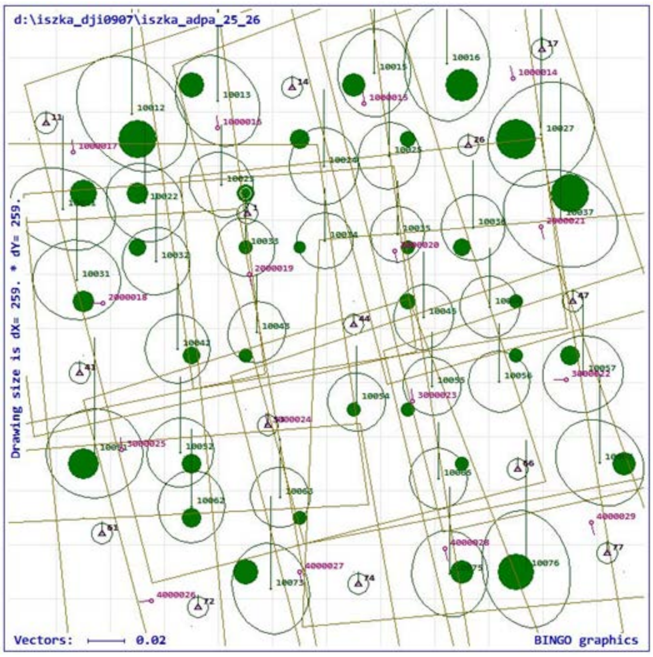

Fig. 8 Error ellipses on new points

V. Conclusions

As a summary we can say that the field resolution of the images was 5 centimetres and after the adjustment the horizontal error was 2 centimetres. We can say that the UgCS software is a user friendly and freeware application and it can be used easily for planning and executing of aerial surveying missions. During the geotagging of the pictures the „yaw," „pitch" and „roll" values were logged, but these values should be interpreted with much care.

References

[1] Kruck, E. – Bingo 6.6 Manual, Bundle Adjustment for Engineering Applications, A Program System for Close Range Photogrammetry and Aerial Triangulation Including Three-Dimensional Geodetic Network Adjustment, Aalen, , pp. 156, 2014

[2] Racurs – User Guide - Processing of UAV Data ver. 5.3., pp. 22, Moscow, 2014

[3] Racurs – User's manual of Photomod Solver 4.4., pp. 75, Moscow, 2008