Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XII, 2023
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

MODERN AND PRECISE SOLUTIONS FOR MAKING ORTHOPHOTOS WITH THE TOPOGRAPHIC DRONE, NECESSARY FOR OBSTACLE STUDIES

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Abstract

The use of the drone offers the possibility of approaching surfaces that are difficult or even impossible to assess with the help of land surveying tools. With the help of professional drones, high-resolution images can be recorded for any type of terrain, with centimetric accuracy, regardless of whether it is an uneven surface, swamps, land where dangerous materials or substances are stored, forested areas or very large areas. Drone photogrammetry is a technique used to measure, metrically and graphically represent an area of land or other objects of interest, using aerial photographs. This photogrammetric method using drones is used to perform topographical measurements with centimetres accuracy and to make digital land models, topographic plans and many other applications for surveying and geodesy on large, drilled areas, agriculture, construction.

Key words: *topographic drone, orthophoto, precision, photogrammetry.*

INTRODUCTION

The UAV drone measurement solution presented in this study was used to perform an obstruction study for the realization of a heliport located on a construction.
For this reason, according to AACR legislation, in order to carry out this obstacle study, it is necessary to identify obstacles from both flight directions, depending on the importance class of the heliport.
These obstacles, respectively the area with all the obstacles in the area related to the proposed heliport could not be achieved in a very short time by classical methods, which is why a modern measurement method was adopted with the help of the drone to ensure a very high precision, respectively through this method to achieve an orthophoto with a resolution of 5 achieve an orthophoto with a resolution of 5 cm/pixels well adapted to identify the obstacles in the researched area.
The purpose of the obstruction study is to determine the airspace around the heliport, in such a way as to allow proper control by the authorities for helicopter operations to be carried out safely and to prevent the heliport from becoming unusable by the appearance of obstacles around it.

MATERIALS AND METHODS

The UAV (aerial vehicle without human personnel on board, a Rebel 1718 drone) technology was used for the presented study.
In the office phase before the measurement, the following steps were taken:

- the zone with the area necessary for the flight was identified (Figure 1);
- a polygon was drawn with the studied area which was loaded into the flight program.

Figure 1. Zone with the area necessary for the flight

Workflow description

The reference geodetic network represents the mathematical support for drawing up all the

plans for the entire proposed location (Băbucă et al., 2014).
The reference geodetic network will ensure the connection of all measurements in a general unitary system (the reference systems are established by the construction designers).
The proposed method - the static and RTK method is the most used method for creating geodetic networks that require very high precision (Băbucă et al., 2016).

Stages in making the ground support network:
- Land recognition;
- Making measurements;
- Processing and compensation of measurements;
- Preparation of reports on the processing and compensation of measurements.

Steps taken:
- Realization of the main network through GPS observations – static methods (Figure 2);
- Realization of the main network through GPS observations - RTK methods (Figure 3) (Băbucă et al., 2018).

Coordinate systems used:
- System1970 stereographic;
- Black Sea Altitudes in 1975.

Figure 2. Rompos Network

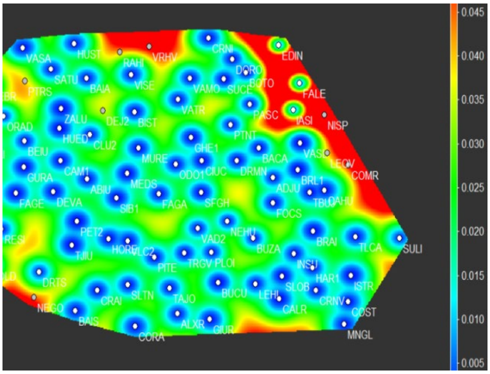

Figure 3. Residual Ionosphere (Network RTK).
The estimated residual ionospheric error for a network RTK user

GPS observations were made with the following equipment:
- Leica System GPS receivers (Figure 4);
- Data RINNEX from GPS Permanent Stations (Slobozia, Cernavodă, Lehliu, Însurăţei).

Figure 4. Leica System GPS receivers

The condition for GPS observations are:
- The geometry of the satellites, in order to ensure the most accurate determination, it is necessary that at the time of observation the satellites have an optimal geometric arrangement (for example, they are not all on the same direction) (Figure 5) (Băbucă et al., 2018).

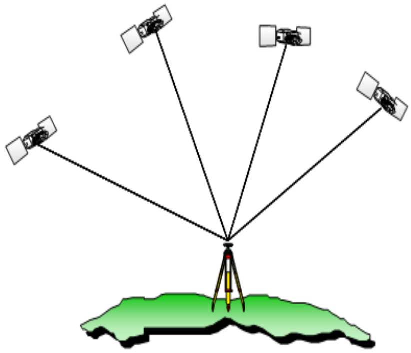

Figure 5. Geometry of the satellites

- The visibility of the signal emitted by the satellite can be distorted or even obstructed by different obstacles (vegetation, constructions, etc.) or it can be received after reflection from different surfaces, thus affecting the accuracy of the determination (Figure 6).

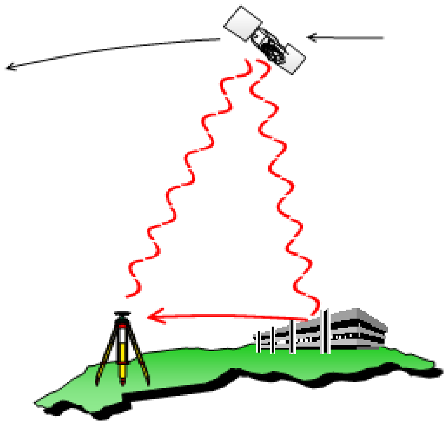

Figure 6. Visibility of the signal

Aero Scanning Methodology
To carry out measurements on the ground, a topographically specific UAV was used, with the precision of GNSS RTK - PPK Technology (Băbucă et al., 2018; https://rompos.ro).
These equipments perform topographical measurements with centimeter precision on hard-to-reach or inaccessible surfaces.
With the help of the drone, was created the digital model of the terrain in autocad format, the point cloud and the orthophoto. The achieved ground resolution is 5cm/pixel.

Presentation of the equipment used
To carry out the study it was used a Rebel 1718 drone, this is a professional airplane - type drone used in surveying and agriculture (Figure 7).

Figure 7. Rebel 1718 drone

The initial parameters are imposed by the useful mass that it must carry in stable flight conditions, but also the chassis structure that allows the placement of sensors and modules in the key points of the systems that I compose it.
Thus, the configuration of the drone exemplified in Figure 7, with the following characteristics (https://fae-drones.com):
- *Coverage:* covers extensive areas of over 1000 Ha with a resolution of 5 cm / pen and lateral coverage of 60% in two hours of flight.
- *Flight time*: 120 minutes with a load of 500 g at a speed of 60 km/h
- Wingspan: 1718 mm
- Fuselage length: 1100 mm
- Fuselage material: Elapor
- Weight in flight: 2500-3800g
- Wing surface: 60 dm ^2
- Recommended flight speed: 60 Km/h
- Maximum flight speed: 110Km/h
- Payload size: 30x13x13 cm
- Maximum flight altitude ASL: 5 Km
- Li-Po 21A/ 4S battery
- *Telemetry*, map navigation and wireless configuration through a PC system via remote control - 60 km.

The studied area

The measurements were made in the Slobozia city area, where a classic mapping mission was performed. The average altitude of the drone during the mission was about 330 m above the ground and about 350 m above the level of the Black Sea.

Purpose of the study: creating a digital elevation model (DEM) and an orthophoto image with an accuracy of 5 cm/ pixel (Figure 8).

Figure 8. Study area - 300 Ha

Survey Data:

- Number of images: 867
- Flying altitude: 303 m
- Ground resolution: 4.45 cm/pix
- Coverage area: 3.21 Km^2
- Camera stations: 867
- Tie points: 2.170.535
- Projections: 5.294.514
- Reprojection error: 0.6 pix

Camera used is a model ILCE-5100 with 6000*4000 resolution. The location of camera is presentet in Figure 9 and the calibration of camera in Figure 10 and Table 1.

In Figure 11 and Tabel 2 we can see the camera locations and error estimates.

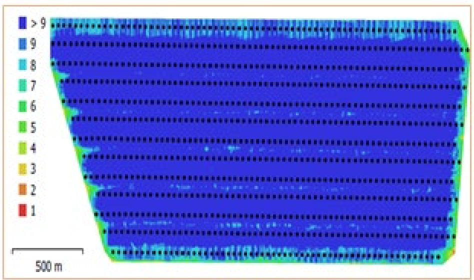

Figure 9. Camera locations and image overlap

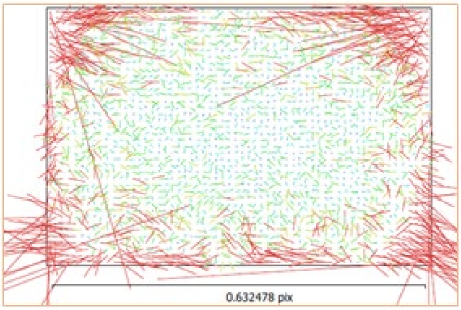

Figure 10. Image residuals for ILCE-5100

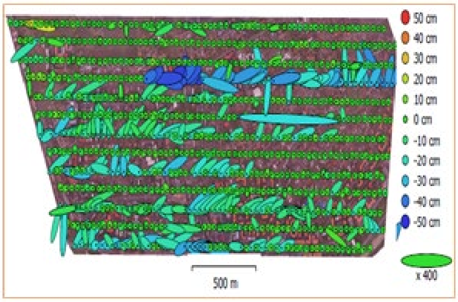

Figure 11. Camera locations and error estimates.
Z error is represented by ellipse color
X,Y errors are represented by ellipse shape
Estimated camera locations are marked with a black dot

Table 1. Calibration coefficients and correlation matrix

	Value	Error	F	Cx	Cy	B1	B2	K1	K2	K3	K4	P1	P2
F	**6577.93**	0.42	1.00	0.13	-0.03	-0.23	0.04	-0.89	0.87	-0.84	0.80	0.12	0.01
Cx	**-63.3359**	0.27		1.00	-0.06	-0.20	0.08	-0.15	0.15	-0.15	0.15	0.98	-0.06
Cy	**-40.7628**	0.22			1.00	-0.08	-0.26	-0.01	0.01	-0.02	0.02	-0.06	0.98
B1	**-0.893444**	0.028				1.00	0.01	0.32	-0.33	0.32	-0.29	-0.20	-0.05
B2	**0.0789858**	0.017					1.00	-0.02	0.02	-0.02	0.02	0.08	-0.26
K1	**-0.13866**	0.0012						1.00	-0.99	0.97	-0.93	-0.16	-0.00
K2	**0.103026**	0.01							1.00	-0.99	0.97	0.16	0.01
K3	**0.161212**	0.035								1.00	-0.99	-0.16	-0.01
K4	**-0.0187057**	0.047									1.00	0.15	0.01
P1	**-0.00101429**	1.7e-05										1.00	-0.07
P2	**0.00171841**	1.4e-05											1.00

Table 2. Average camera location error

X error (cm)	**Y error (cm)**	**Z error (cm)**	**XY error (cm)**	**Total error (cm)**
15.7953	7.89966	10.9639	17.6606	20.7871

X - Easting, Y - Northing, Z - Altitude

RESULTS AND DISCUSSIONS

In Figure 12 we can see the reconstructed Digital Elevation Model (DEM) with resolution: 4.45 cm/pix and point density 504 points/m².
The processing parameters are presented in Table 3 and Ortofotoplan in Figure 13.

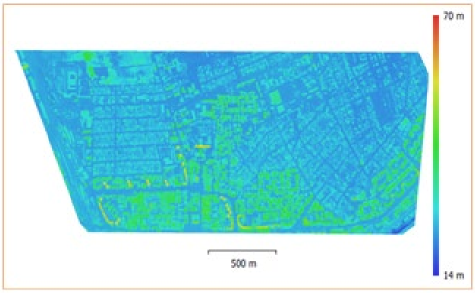

Figure 12. Reconstructed DEM

Table 3. Processing parameters

General	
Cameras	867
Aligned cameras	867
Shapes	
Polygons	1
Coordinate system	Stereo 70
Rotation angles	aw, Pitch, Roll
Point Cloud	
Points	2,170,535 of 3,305,505
RMS reprojection error	0.131075 (0.599675 pix)
Max reprojection error	0.5416 (3.98802 pix)
Mean key point size	4.29851 pix
Point colors	3 bands, uint8
Average tie point multiplicity	2.84331
Alignment parameters	
Accuracy	Highest
Generic preselection	Yes
Reference preselection	Source
Key point limit	500,000
Tie point limit	50,000
Matching time 4 hours	4 hours 25 minutes
Matching memory usage	3.65 GB
Alignment time	37 seconds
Alignment memory usage	990.07 MB
Optimization parameters	
Parameters	f,b1,b2,cx,cy,k1-k4,p1,p2
Fit additional corrections	Yes
Optimization time	2 minutes 33 seconds
Software version	1.6.5.11249
File size	274.25 MB
Depth Maps	
Count	863
Depth maps generation	
Quality	High
Filtering mode	Moderate
Processing time	5 hours 34 minutes
Memory usage	8.53 GB
Software version	1.6.5.11249
File size	24.27 GB
Dense Point Cloud	
Points	2,042,276,561
Point colors	3 bands, uint8
Depth maps generation	
Quality	Ultra High
Filtering mode	Moderate
Processing time	5 hours 34 minutes
Memory usage	8.53 GB
Dense cloud generation parameters	
Processing time	8 hours 29 minutes
Memory usage	32.84 GB
Software version	1.6.5.11249
File size	62.93 GB
DEM	
Size	90,582 x 47,572
Coordinate system	Stereo 70
Reconstruction parameters	
Source data	Dense cloud
Interpolation	Enabled
Processing time	42 minutes 51 seconds
Memory usage	704.74 MB
Software version	1.6.5.11249
File size	8.69 GB
Orthomosaic	
Size	62,776 x 28,025
Coordinate system	Stereo 70
Colors	3 bands, uint8
Reconstruction parameters	
Blending mode Mosaic	Mosaic
Surface	DEM
Enable hole filling	Yes
Processing time	25 minutes 23 seconds
Memory usage	2.88 GB
Software version	1.6.5.11249
File size	12.65 GB
System	
Software	Agisoft Metashape Pro
Software version	1.6.5 build 11249
OS Windows	64 bit
RAM	63.93 GB
CPU	Intel(R) Core, i7-9700
GPU(s)	GeForce GTX 1080 Ti

Figure 13. Ortofotoplan - Final results

The deliverables obtained from the measurements with the UAV drone, the digital elevation model of the landscape and the orthophoto image with a precision of 5cm/ pixel, allowed the realization of the study of obstacles necessary for the heliport design (Figure 14).

Figure 14. Obstruction study

Before starting your drone mapping here are the things you will need to consider:

- the type of drone used specific to each project will always use a high resolution camera and integrated GPS module.
- methods of investigation if you want to produce a truly accurate topographic map you will need to make measurements on the ground in the form of ground control points.
- Survey planning software and data processing software will be used for data processing that ensures increased confidence in obtaining correct results, exemple Pix4D, Drone Deploy and Precision Mapper, mapping software solutions.
- Mapping software: A 3D topographic model will allow us to visualize a lot of information that we can analyze and study.

CONCLUSIONS

At the end of the study we can make the following conclusions:

- the method proposed and used in the creation of the orthophoto image necessary for the realization of the obstruction study was successfully completed.
- the method proposed and analyzed based on the data and values obtained is confidently recommended for other types of works and engineering studies.
- after processing the images, the accuracy of the resulting orthophoto image is 5cm/ pixel
- precision of Digital Elevation Model – (resolution: 4.45 cm/pix, point density: 504 points/m^2).

ACKNOWLEDGEMENTS

This research work was carried out with the support of Fae Drones, 287 Theodor Pallady Blvd, IOR2 building, 4th floor, main building. District 3, 032267, Bucharest.

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