Comparative Study on Executing Topographic Plans Using UAVs

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Keywords: UAV, control point, camera, topographic plan, Digital Terrain Model.

SUMMARY

The present paper aims to carry out a comparative study on how the digital model can be obtained using the images taken with a camera mounted on a UAV, in two cases:

- The case where there are control points determined on the ground
- The case where there are no control points determined on the ground.

To verify the consistency of the digital model, field verification points were determined using GNSS receivers.

Basically, on the same area of interest were carried out GNSS RTK measurements and two flights with two different types of UAVs: **SenseFly eBee X** and **DroneZone XF8-CT**.

The flight was carried out at the same height and with medium resolution cameras (Sony A7R 35mm 36 Mpix and SenseFly Aeria X 24MPix). The GNSS receivers were different. Thus, for the **DroneZone XF8-CT** a GNSS receiver of the **u-Blox NEO8M** type was used and for SenseFly eBee X a **GNSS RTK** receiver of the **TRIMBLE BD93** type and a **SenseFly GeoBase** base.

To establish the consistency of the data, 28 verification points were measured on the ground with GNSS technology.

The measurements for determining the position of the control points were performed on different days, using a **Leica GS08 Plus GNSS** system, connected to the National Network of Permanent GNSS Stations (RN-SGP) through the ROMPOS system.

For the flight made with DroneZone XF8-CT, 6 control points were determined.

For the flight made with SenseFly eBee X, only the data taken by the RTK system from the SenseFly eBee X UAV were used.

The data were processed and a Digital Terrain Model was created for each flight. Finally, a comparison was made between the two Digital Terrain Models, in order to determine the differences between them, but also the differences as against the RTK verification measurements made with the **Leica GS08 Plus GNSS** system.

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1. METHODOLOGY

1.1 Making the first variant of the digital terrain model.

The area where the study was conducted is the commune of Schitu, Giurgiu County, Romania. In the area there have been works for the introduction of the systematic cadastre, respectively the measurement of each property. For this, a **DroneZone XF8-CT** flight was equipped with a **u-Blox NEO8M** GNSS receiver and a **Sony A7R 35mm 36 Mpix** camera. Also, the property limits were determined with a total station Leica TS06 type and **Leica GS08 Plus** GNSS receivers. To georeferencing (scaling) the images taken with the UAV system, 6 control points have been determined, pre-signaled on the ground, before he flight.

When designing the flight, we took into account the following considerations:

1. Depending on the products to be obtained, the longitudinal and transverse covers between the images are determined, as well as the height and the speed of flight;
2. Establishing the orientation of the flight strips;
3. Determining the best days and times for carrying up the photogrammetric flight;
4. Analysis of the weather; information is collected from weather stations near the area of interest;
5. Establishing the final flight route that is handed over to the pilot or operator of the photogrammetric camera.

The longitudinal coverage was of 80% and the transverse coverage of 50% to obtain in the end a trueortophoto.

The strips were established according to figure 1.1.1

Simple Options
Camera: Sony A7R
Altitude (m): 140
Angle [deg]: 171
☑ Camera top facing forward
Flying Speed (est) (m/s): 10
☑ Use speed for this mission
☑ Add Takeoff and Land WP's
☑ Use RTL
Split into x segments: 1

Display
☑ Boundary
☑ Markers
☑ Grid
☐ Internals
☐ Footprints
☑ Advanced Options

Control-S to save to file
Control-O to load form file

```
Stats
Area:                1710178 m^2   Pictures:           821              Flight Time (est):   56:19 Minutes   Min Shutter Speed: 1/819
Distance:            27.03 km      No of Strips:       12               Photo every (est):   3.00 Seconds
Dist between images: 30 m          Footprint:          179.5 x 120 m    Turn Dia (at 45d):   29 m
Ground Resolution:   2.44 cm       Dist between lines: 71.8 m           Ground Elevation:    54-75 m
```

Figure 1.1.1 Flight strips.

The pre-signaling was marked on the ground either with paint or single-use plates, as in figure 1.1.2.

Figure 1.1.2 Pre-signaling the control points on the ground

At the time of flight the flight conditions were optimal: clear sky, temperature over 5 degrees Celsius, wind speed below 2 m /s.

Following the data processing with the Agisoft software, a cloud of points was obtained. In order to obtain the Digital Terrain Model (DTM), we have performed the unsupervised (automatic) classification and then the supervised (manual) classification of the cloud of points in order to establish the points that belong to the ground class.

By triangulating the points in the ground class, we obtained a solid model known as the Digital Terrain Model (DTM) - Figure 1.1.3.

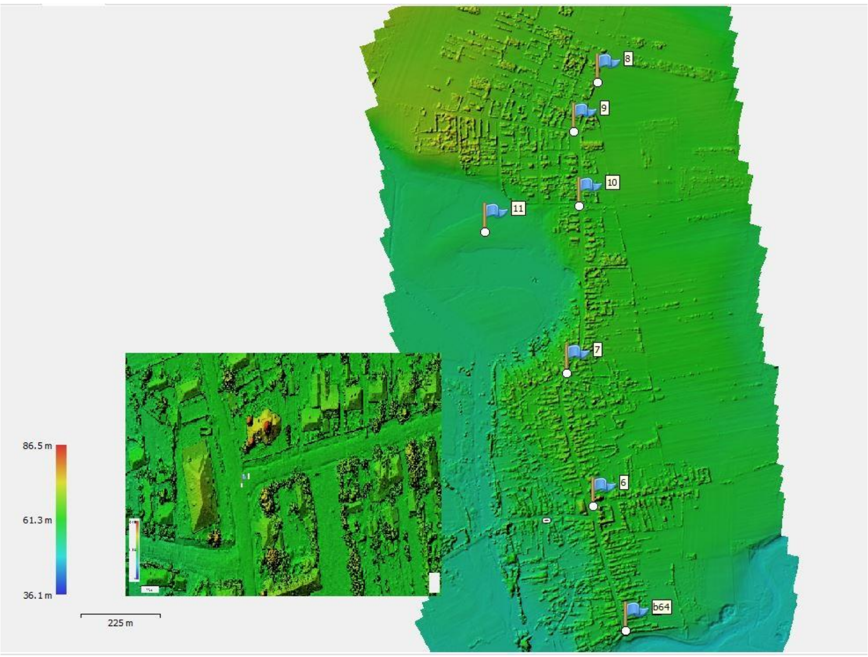


Figure 1.1.3 The Digital Terrain Model obtained from the cloud of points processing

The flight was realized in the days: 06.02 -07.02.2018.

1.2 Carrying out the second digital terrain model

A new UAV model has launched on the market, **SenseFly eBee X**, equipped with a **TRIMBLE BD93** type **GNSS RTK** receiver, a **SenseFly GeoBase** base and a **SenseFly Aeria X 24MPix** camera. From the description that the seller made, it turned out that there was no need for control points (landmarks) for georeferencing.

We decided to do a comparative study, to convince ourselves that the newly developed system has the performances described by the seller.

Thus, we redo the flight we had made with the first type of UAV, on the same area, but without determining control points on the ground.

The flight was made during the 27 November 2018 period.

The data were processed with the same type of program and we obtained a new digital terrain model, for the same area.

1.3 Verification of results.

During the systematic cadastral work, as specified in chapter 1.1, we performed measurements with the total station and GNSS receivers to determine the property limits. To do this, we created a topographic network of densification, determined with the Leica GS08 Plus GNSS receivers connected to the National Network of Permanent GNSS Stations (RN-SGP) through the ROMPOS system. The network was made of wooden stakes.

From this network were selected a number of 31 points spread over the entire area over which the flight was made and the digital terrain model was obtained (Figure 1.3.1). The accuracy of determining these control points is ± 3 centimeters. The points were named: B01, B02, B03, B04, B05, B06, B07, B08, B09, B10, B11, B12, B15, B16, B19, B21, B23, B38, B43, B50, B54, B55, B65 , B68, 5, 6, 7, 8, 9 10 and B64.

Figure 1.3.1 Position of the control points

The altitudes of these points were noted in a table (Table 2.1), together with the name of each (column marked with 1). The first digital model was loaded in the Agisoft program and, based on the planimetric position of each of the 28 points it was extracted from the digital terrain model, the altitude of each point and was noted in the table (column noted with 2).

Similarly, the altitude of each of the 31 points of the second digital terrain model was determined and noted in the table, in the respective column (noted with 3).

2. RESULTS

Following the results obtained in Chapter 1.3, table 2.1 was made, in which we have:

- In the column marked with 1, the altitudes of the 31 control points determined on the ground with GNSS technology.
- In the column marked with 2, the altitudes of the 31 control points extracted from the digital terrain model obtained with the UAV **DroneZone XF8-CT**.

- In the column marked with 3, the altitudes of the 31 control points extracted from the digital terrain model obtained with UAV **SenseFly eBee X.**

The following columns are the differences between the altitudes of the control points determined in the 3 variants.

Thus, column 4 represents the difference between the altitudes obtained from GNSS measurements and the digital model obtained with the UAV **DroneZone XF8-CT**.

Column 5 represents the difference between the altitudes obtained from GNSS measurements and the digital model obtained with UAV **SenseFly eBee X.**

Column 6 represents the difference between the altitudes obtained from the digital model obtained with the UAV **DroneZone XF8-CT** and the digital model obtained with the UAV **SenseFly eBee X**.

A graph of the altitude differences obtained in the 3 variants was made.

3. CONCLUSIONS

We start from the hypothesis that the correct altitudes are those determined directly on the ground, with the GNSS technology, using the permanent stations of the National Agency for Cadastre and Real Estate Advertising. From the presented values, the altitudes extracted from the model made with **DroneZone XF8-CT** are very close to those determined on the ground. This is because 6 ground control points were used, which fixed the digital model.

The altitude values determined with **SenseFly eBee X** are about 31 centimeters higher on average.

Between the GNSS measurements and the digital model obtained from the **DroneZone XF8-CT** flight, the largest negative difference is –14 centimeters and the largest positive is +10 centimeters.

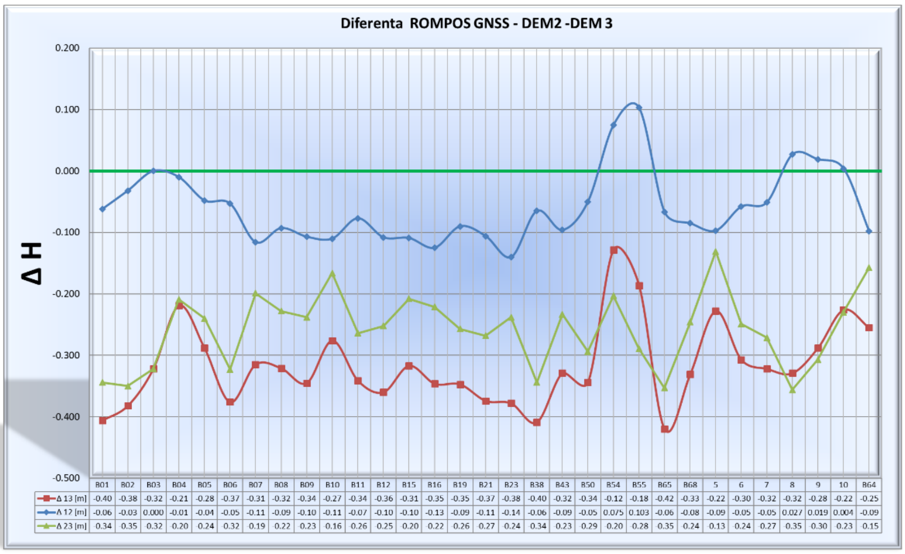
These differences are due to the fact that points B23 and B55 are located in grassy areas, where the altitude given by the drone is not very correct because it stops at grass level and not at ground level. From Figure 3.1 it can be seen that the two points are not located on a flat area, such as an asphalt road, a concrete platform, etc.

The mean difference between the two altitudes is -5.9 centimeters and falls within the accuracy of the GNSS determined point network, of ± 3 centimeters.

Table 2.1 Measurement results

Point	**Measured ROMPOS GNSS [m]**	**Measured with DEM Drone Zone [m]**	**Measured with DEM Pix4D eBee RTK [m]**	**Δ 12 [m]**	**Δ 13 [m]**	**Δ 23 [m]**
	column 1	**column 2**	**column 3**	**column 4**	**column 5**	**column 6**
Measurements 07.17.2018						
B01	**64.190**	**64.252**	**64.596**	**-0.062**	**-0.406**	-0.344
B02	**63.910**	**63.942**	**64.292**	**-0.032**	**-0.382**	**-0.350**
B03	**63.930**	**63.930**	**64.252**	**0.000**	**-0.322**	**-0.322**
B04	**63.860**	**63.870**	**64.079**	**-0.010**	**-0.219**	**-0.209**
B05	**63.750**	**63.798**	**64.038**	**-0.048**	**-0.288**	**-0.240**
B06	**63.450**	**63.503**	**63.826**	**-0.053**	**-0.376**	**-0.323**

B07	**63.350**	**63.466**	**63.665**	**-0.116**	**-0.315**	**-0.199**
B08	**63.190**	**63.283**	**63.511**	**-0.093**	**-0.321**	**-0.228**
Measurements 07. 26.2018						
B09	**63.23**	**63.337**	**63.575**	**-0.107**	**-0.345**	**-0.238**
B10	**62.8**	**62.91**	**63.076**	**-0.110**	**-0.276**	**-0.166**
B11	**62.290**	**62.367**	**62.631**	**-0.077**	**-0.341**	**-0.264**
B12	**62.590**	**62.698**	**62.950**	**-0.108**	**-0.360**	**-0.252**
B15	**63.140**	**63.249**	**63.457**	**-0.109**	**-0.317**	**-0.208**
Measurements 07. 27.2018						
B16	**63.24**	**63.365**	**63.586**	**-0.125**	**-0.346**	**-0.221**
B19	**62.58**	**62.67**	**62.927**	**-0.09**	**-0.347**	**-0.257**
B21	**62.38**	**62.486**	**62.754**	**-0.106**	**-0.374**	**-0.268**
B23	**63.77**	**63.91**	**64.148**	**-0.14**	**-0.378**	**-0.238**
B38	**63.560**	**63.625**	**63.969**	**-0.065**	**-0.409**	**-0.344**
B43	**63.640**	**63.736**	**63.969**	**-0.096**	**-0.329**	**-0.233**
Measurements 08. 29.2018						
B50	**63.100**	**63.150**	**63.444**	**-0.050**	**-0.344**	**-0.294**
B54	**63.190**	**63.115**	**63.318**	**0.075**	**-0.128**	**-0.203**
B55	**62.590**	**62.487**	**62.776**	**0.103**	**-0.186**	**-0.289**
Measurements 09. 04.2018						
B65	**62.430**	**62.497**	**62.850**	**-0.067**	**-0.420**	**-0.353**
B68	**59.650**	**59.735**	**59.981**	**-0.085**	**-0.331**	**-0.246**
Measuremens 11. 27.2018 Leica GS8						
5	**61.850**	**61.947**	**62.078**	**-0.097**	**-0.228**	**-0.131**
6	**63.788**	**63.846**	**64.095**	**-0.058**	**-0.307**	**-0.249**
7	**63.625**	**63.676**	**63.947**	**-0.051**	**-0.322**	**-0.271**
8	**63.947**	**63.920**	**64.276**	**0.027**	**-0.329**	**-0.356**
9	**63.541**	**63.522**	**63.829**	**0.019**	**-0.288**	**-0.307**
10	**62.192**	**62.188**	**62.418**	**0.004**	**-0.226**	**-0.230**
B64	**61.874**	**61.972**	**62.129**	**-0.098**	**-0.255**	**-0.157**
			Δ Minimum	**-0.140**	**-0.420**	**-0.356**
			Δ Mean	**-0.059**	**-0.317**	**-0.258**
			Δ Maximum	**0.103**	**-0.128**	**-0.131**



	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	B15	B16	B19
Δ 13 [m]	-0.40	-0.38	-0.32	-0.21	-0.28	-0.37	-0.31	-0.32	-0.34	-0.27	-0.34	-0.36	-0.31	-0.35	-0.35
Δ 12 [m]	-0.06	-0.03	0.000	-0.01	-0.04	-0.05	-0.11	-0.09	-0.10	-0.11	-0.07	-0.10	-0.10	-0.13	-0.09
Δ 23 [m]	-0.34	-0.35	-0.32	-0.20	-0.24	-0.32	-0.19	-0.22	-0.23	-0.16	-0.26	-0.25	-0.20	-0.22	-0.26

	B21	B23	B38	B43	B50	B54	B55	B65	B68	5	6	7	8	9	10	B64
Δ 13 [m]	-0.37	-0.38	-0.40	-0.32	-0.34	-0.12	-0.18	-0.42	-0.33	-0.22	-0.30	-0.32	-0.32	-0.28	-0.22	-0.25
Δ 12 [m]	-0.11	-0.14	-0.06	-0.09	-0.05	0.075	0.103	-0.06	-0.08	-0.09	-0.05	-0.05	0.027	0.019	0.004	-0.09
Δ 23 [m]	-0.27	-0.24	-0.34	-0.23	-0.29	-0.20	-0.28	-0.35	-0.24	-0.13	-0.24	-0.27	-0.35	-0.30	-0.23	-0.15

Graph 2.1 - Differences in altitude

The digital model made from the **DroneZone XF8-CT** flight is different on average against the topographic network with -31.7 centimeters. It is clear that the relatively constant difference comes from the fact that on this flight we had no control point, so that the digital model is higher than the real model, determined by measurements referring to a system of verified altitudes.

The conclusion is that even if we use a UAV that has a powerful GNSS receiver, a few control points are however needed in order to have the absolute altitude of the digital model as close to the reality on the ground.

4. THE SIGNIFICANCE OF THE WORK.

Currently, the UAV technology for the realization of topographic plans is increasingly used. UAVs are equipped with GNSS receivers that give the position of the points with very high accuracy.

Often users prefer not to determine control points anymore, considering that the results obtained are correct.

The present paper demonstrates that, in order to have a correct topographic plan, close to the reality on ground, at a UAV flight, control points measured on the ground are required.

Figure 3.1 Placement of the control points B.23 and B.55

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