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Determining the optimum number of ground control points for obtaining high precision results based on UAS images

Valeria-Ersilia Oniga[1,*], Ana-Ioana Breaban[2] and Florian Statescu[2]

[1] Department of Terrestrial Measurements and Cadastre, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, "Gheorghe Asachi" Technical University of Iasi, Professor Dimitrie Mangeron Boulevard 67, Iași, Romania; ersilia.oniga@tuiasi.ro

[2] Department of Hydroamelioration and Environmental Protection, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, "Gheorghe Asachi" Technical University of Iasi, Professor Dimitrie Mangeron Boulevard 67, Iași, Romania; anaioana2004@yahoo.co.uk; fstatesc@hidro.tuiasi.ro

* Correspondence: ersilia.oniga@tuiasi.ro; Tel.: +40-745-634-472

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Abstract: The ground control points (GCPs) are used in the process of indirect georeferencing the Unmanned Aerial Systems (UAS) images. A minimum of 3 ground control points (GCPs) is required, but increasing the number of GCPs will lead to higher accuracy of the final results. The aim of the study is to provide the answer to the question of how many ground control points are necessary in order to derive high precision results. To obtain the results, an area of about 1 ha has been photographed with a low-cost UAS, namely DJI Phantom 3 Standard at two different heights: 28 m and 35 m above ground, the camera being oriented in nadiral position and a number of 50 ground control points were measured using a total station. In the first and the second scenario, the UAS images were processed using the Pix4D Mapper Pro software and 3DF Zephyr respectively, by performing a full bundle adjustment process, the number being gradually increased from 3 GCPs to 40. The third test was made with 3DF Zephyr Pro software using a free-network approach in the bundle adjustment. Also, the point clouds and the mesh surfaces derived automatically after using the minimum and the optimum number of GCPs respectively, were compared with a terrestrial laser scanner (TLS) point cloud. The results expressed a clear overview on the number of GCPs needed for the indirect georeferencing process with minimum influence on the final results.

Keywords: UAS images; DJI Phantom 3 Standard; ground control point; 3DF Zephyr Pro software; accuracy assessment;

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1. Introduction

Multiple photogrammetry applications are based on Unmanned Aerial Systems (UAS) due to cost efficient data acquisition and high spatio-temporal resolution imagery. Widely-used in various fields like land surveying and construction, the ground control points (GCPs) can greatly increase the accuracy of the 3D information and their measurement is an important aspect for georeferencing the UAS image blocks. The ground control points are used in the process of indirect georeferencing the Unmanned Aerial Systems images, a minimum of 3 ground control points being required, but increasing the number of GCPs will lead to higher accuracy of the final results i.e. point cloud, 3D mesh, orthomosaic or digital surface model (DSM). Moreover, exceeding the number of ground control points is a time-consuming process, both in the field and computationally.

A series of studies have been conducted on determining the optimum number of ground control points, but mainly for georeferencing the DSM [1-5], the orthoimage [2,3,6,7] and the point clouds [8] generated by processing the UAS images. Tahar et al. [7] studied the influence of the number and distribution of the GCPs for georeferencing the UAS images, but he did not use the SfM algorithm for image matching. It was demonstrated that increasing the number of ground control points will increase the accuracy of the final products [1,2]. Even so, the accuracy of the final products derived from UAS images is influenced by different factors, such as: camera's focal length, flight altitude, camera orientation, image quality, processing software, type of UAS system (fixed wind or rotary wind), the precision with which targets can be measured and matched [1,8], each study contributes to the products improvement obtained by UAS technology.

The main aim of this study is to determine the optimum number of ground control points in order to georeference a block of nadiral UAS images taken at two heights, in different scenarios and using two different software i.e. Pix4D Mapper software (commercialized by Pix4D and widely used in photogrammetric and remote sensing community) and 3DF Zephyr Pro software (that promises a lot in 3D reconstruction area, which is commercialized by 3Dflow) and to assess the accuracy of the final products i.e. dense point cloud and mesh surface (not only the DSM as mentioned in other studies [1-5]) by comparing the results with terrestrial laser scanner (TLS) point cloud and total station measurements, for three cases: using 3 GCPs and the determined optimum number of GCPs. Also, as already mentioned in Tonkin et al. [5], the accuracy of GCPs directly influence the accuracy of the final products, reason why for this study all GCPs were measured with precision of millimetres using a total station in a local coordinate system, by designing a spatial geodetic network.

In this perspective, an area of about 1 ha has been photographed with a low-cost UAS, namely DJI Phantom 3 Standard, at two different heights and a number of 50 ground control points, uniformly distributed over the study area, were measured using a total station.

2. Study area

The study area of about 1 ha is located near the Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering from "Gheorghe Asachi" Technical University of Iasi, Romania, covering the building roof, the parking lot and the green area in the vicinity.

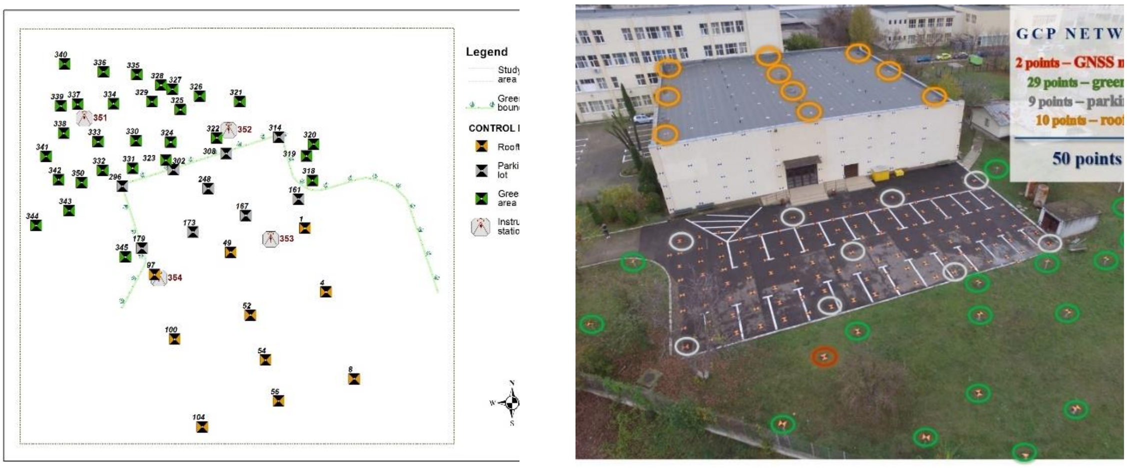
3. Materials and Methods

3.1. Measurement of ground control points (GCPs)

Within the project, the solution to design a spatial geodetic network determined by GNSS technology has been chosen, providing a homogeneous and unitary precision of all three components of spatial positioning. The spatial geodetic network was designed with 4 points, two of which were grounded in the green area behind the Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, and the other two were located on the roof, in the northern part of the building. For the present research, a local reference and coordinate system was adopted.

There were grounded 50 uniformly distributed points in the study area: 29 points in the green space (reinforced concrete poles to ensure different heights), 2 points of the GNSS network (concrete), 9 points in the parking lot (metallic bolts) and 10 points on the roof (marked with paint) (Figure 1).

Each new point was double measured using a mini prism from the ends of a GNSS base. For determining the final spatial coordinates of the detail points, the weighted indirect compensation model was applied for each new point, obtaining a total accuracy of a few millimetres. To assure the visibility on the UAS images, the points were marked using plexiglass plates that have been drawn with two black and orange triangles, 3 mm thick, 40 cm × 40 cm, with a central hole of 5 mm diameter.



(**a**) (**b**)

Figure 1. (a) The spatial distribution of the 50 GCPs and the study area limit in the local coordinate system, (b) UAS image with the location of the 50 GCPs.

3.2. Data Acquisition

The area of interest has been photographed with DJI Phantom 3 Standard, a low-cost UAS, at two different heights: 28 m and 35 m above ground. The low-cost UAS platform has a built-in digital camera equipped with a 6.2031 mm by 4.6515 mm image sensor capable of taking images with a resolution of 12 MP and 4000 x 3000 pixels. The flight planning was made with Pix4D software, choosing the longitudinal and transversal overlap of 80% and 40%, respectively, the camera being oriented in nadiral position. For 28 m height, the flight was made in double grid, 122 images being acquired with 1 cm GSD while for 35 m, the flight was made in single grid, 51 images with the GSD of 1.24 cm being acquired. In order to assess the accuracy of the point clouds and the mesh surfaces automatically generated based on UAS images, a comparison was done with a TLS point cloud. In addition, this resulted from registering four point clouds obtained with Maptek I-Site 8820 terrestrial laser scanner from the ends of the two GNSS bases, using the direct georeferencing process.

3.3. Data processing

As mentioned before, the proposed tests have been made taking into account different scenarios. In all the scenarios, the UAS images were processed with a minimum number of ground control points while the 47 remaining control points served as check points (CP) for accuracy assessment. For the evaluation, the CPs were manually measured on each oriented image, the coordinates being compared with the ones determined with high precision by the GNSS technology. Then, the number of GCPs was gradually increased up to 40, the accuracy being checked on the remaining 10 CPs. The Euclidian distance between the two coordinate sets for a point was calculated based on the measured coordinates, followed by the determination of the root mean square error (RMSE).

For UAS image processing using the 3DF Zephyr Pro software, the images were imported into the software and the project was processed without specifying the type of camera and the calibration parameters, so for the interior and exterior orientation parameters for each camera position an approximation was made based on the EXIF information. All the GCPs were manually measured on each oriented image they appear (minimum 3). The file containing this information was exported and based on this project, the new ones were created (a project for 3GCPs and 47 CPs, one for 4GCPs and 46 CPs etc.), each time importing the same image measurements for the GCPs. In order to bring the results into the local coordinate system, the option “Scale model with control points” was chosen. On the following stage, a table with the coordinates of all the GCPs appears and it was checked “Constraint” and “Control” boxes for the control points (3-40 control points) and only the “Control” box for the points serving as check points (47-10 check points). The constraints confidence weight was left as default value i.e. 50%. Furthermore, it was selected the "Perform Bundle Adjustment" option and for "Advanced settings" the interior orientation with radial and tangential parameters adjustment was chosen. After running the bundle adjustment process, the errors for each control and check point were displayed in pixels and in meters. The coordinates of all 50 GCPs were exported and compared with the coordinates determined with high precision. The options "Aerial" for "Category" and "Default" for "Presets" were chosen in order to generate the dense point cloud. For the mesh surface creation, the options "Aerial" for "Category" and "Default- Sharp Features" for "Presets" were chosen. To perform the third scenario with the 3DF Zephyr Pro software, i.e. using a free-network approach in the bundle adjustment and only at the end of the bundle adjustment process, the GCPs have to be used for applying a similarity (Helmert) transformation in order to bring the image network results into the desired reference coordinate system, the option "Perform Bundle Adjustment" remains unchecked.

Processing in Pix4D implies several steps, but mainly consists in importing the desired images in a new project and regarding the "Image properties" and "Output/GCP Coordinate System", the Arbitrary (m) coordinate system was selected and the "Geolocation" option was not applied in the process. Therefore, as "Template" the 3D Maps was chosen, being suitable for the project's applications (is recommended for nadir flights with a high overlap and generates as deliverables the point cloud, 3D mesh, DSM and the orthomosaic). As an advanced processing option, for the matching strategy it was used the geometrically verified matching. With "GCP/MTP Manager", the file with the control points was imported as well as the corresponding marks for each image (the same marks exported from the 3DF Zephyr Pro software), and after the horizontal and vertical accuracy (m) was changed to 0.002, the involved GCP were selected by changing the "Type" while the remaining points were left as Manual Tie Point (MTP). After the initial processing, for the second stage, point cloud and mesh generation, the default options were applied.

4. Results

4.1. Results corresponding to 28 m height flight

When using the Pix4D software and a full bundle adjustment process, for the minimum number of GCPs it was obtained a RMSE of 81 cm, calculated for 47 CPs whereas for the maximum number, i.e. 40 GCPs, it was obtained a RMSE of 2 cm, calculated for the remaining 10 CPs, although after only 5 GCPs the error decreases down to 28 cm from 53 cm (Figure A1b, Table D1). The analysed results presented in Appendix A, show that the sub-decimetre error is obtained with 12 GCPs, and the optimum number of GCPs for georeferencing the nadiral UAV images is 14, as from this point the errors varies in range of 1 cm until reaching 36 GCPs, for which the RMSE is 1.6 cm.

When using the 3DF Zephyr Pro software and a full bundle adjustment process, for the minimum number of GCP it was obtained a RMSE of 49 cm while for the maximum number, i.e. 40 GCPs the obtained RMSE is 2.5 cm (Figure A1a, Table D1). As expressed by the results presented in Appendix A, the sub-decimetre error is obtained with 14 GCPs, and the optimum number of GCPs for georeferencing the nadiral UAV images is 20, as from this point the errors varies in range of 1 cm until reaching 36 GCPs, where the RMSE is 2.6 cm.

Regarding the third test made with 3DF Zephyr Pro software, it was obtained for the minimum number of GCP a RMSE of 61.1 cm and for the maximum number a RMSE of 27.1 cm (Figure A3a).

4.2. Results corresponding to 35 m height flight

Considering the Appendix A data for Pix4D software, can be underlined that the sub-decimetre error is achieved with 14 GCPs and that 15 GCPs represents the optimum number for georeferencing the nadiral UAV images, as for the following tests the errors varies within 1 cm (Figure A2b, Table D2). Similarly, concerning the case of 3DF Zephyr Pro software, the optimum number of GCPs is also 15 (Figure A2a, Table D2). Comparing the two software in terms of the minimum error, 7 cm corresponds to Pix4D software when using 32 GCPs and, respectively, 8.4 cm to 3DF Zephyr Pro for 19 GCPs. On the other hand, the third case of image processing with 3DF Zephyr Pro software without performing a bundle adjustment, the minimum number of GCP obtained a RMSE of 1.32 cm whereas the maximum number has a RMSE of 28.8 cm (Figure A3b).

To determine the accuracy of the 3D point clouds and mesh surfaces (Appendix B, C), it was utilized the comparison method between the point cloud and a reference mesh surface, considered for this case study the mesh created based on the TLS data. The comparisons were made using the "Distance-Cloud/Mesh Dist" function from the "Tools" menu implemented into CloudCompare software, being calculated the Hausdorff distances between each point and the corresponding triangle surface. The calculated distances were summarized in Table 1.

Table 1. Standard deviation obtained for the UAS points and vertices of the mesh triangles respectively, automatically generated in Pix4D and 3DF Zephyr software for the two flights.

Software	28 m flight		35 m flight	
	Point cloud s[cm]	Mesh s[cm]	Point cloud s[cm]	Mesh s[cm]
Pix4D (3 GCPs)	98.6	86.7	65.4	57.7
3DF Zephyr (3 GCPs)	55.5	46.6	80.7	79.1
Pix4D (optimum GCPs)	9.8	12.6	8.0	8.8
3DF Zephyr (optimum GCPs)	10.4	12.4	7.1	8.7

4. Discussion

Before image processing in Pix4D, several tests were made to assure the right workflow. For both flights, 5 to 18 cameras (for 35 m and 28 m, respectively) remained uncalibrated when the settings were left as default and for improving the number of calibrated cameras without adding more control points, after various tests like importing the GCP after the initial processing (resulted 1 block with 5 uncalibrated cameras for 35 m) or running the project without MTP (resulted 2 image blocks and 4 uncalibrated cameras for 28 m), changing the coordinate system for the entire project and importing the images without geolocation gave the best results: 1 image block with 1 uncalibrated camera for 35 m and 6 cameras for 28 m. On the other hand, from a time-consumption perspective, it was verified if the computed position of the control points remains unchanged when the project is overwritten and optimized (e.g. when computing the project from X GCP to X+1 GCP). The situation where a new project is done each time is more beneficial because in the first situation the results from the first project influence the ones from the following project and for avoiding any errors is better to process independently each scenario. For a quick overview on the processed project, the Quality Report offers various details including information of GCP, section where two points, 49 and 97, are listed in red as if it weren't taken into consideration but when checking their properties in "rayCloud" the positions are computed. Moreover, the rayCloud offers the user the possibility to export the points as shapefile or other similar formats but not table format extensions (e.g. txt).

The differences between the RMSE obtained for each number of GCPs by processing the projects with Pix4D software and Zephyr Pro software respectively, are very similar in range of a few millimetres up to 3 cm, except the first three case: using 3, 4 and 5 GCPs when the RMSE is with 40% smaller in the case of 3DF Zephyr Pro software for the 28 m flight, the reason being unclear. Moreover, when using the 3DF Zephyr Pro software all images were orientated without making any additional steps. The RMSE is influenced by the errors encountered in some CP points namely 1, 49 and 97 situated on the roof edge. The optimum number of GCPs for georeferencing the UAS images when using the Pix4D software was 14 for the 28 m flight and 15 for the 35 m flight and when using the 3DF Zephyr Pro software the optimum number was 20 for the 28 m flight and 15 for the 35 m flight, similar results being reported in [3] but for georeferencing a Digital Surface Model derived from a 120 m flight. The number of GCPs had a very small influence on RMSEx and RMSEy starting with 6 GCPs used in the georeferencing process, as it can be seen from the graphics reported in Figure A1, A2 and A3 and the flight altitude had not significant influences on RMSEz, contrary to the results reported in [2]. Moreover, increasing the number of GCPs had a significant influence on RMSEz until a certain number was reached and it increased the accuracy of the final products as also mentioned in [1,2].

Very large errors were found in the area situated outside the surface covered by the GCPs (the parking lot situated on the right side of the building) being approximately 3 m when using only 3 GCPs, decreasing to a decimetre level when using the optimum number, but still being five times larger than those encountered in GCPs area.

5. Conclusions

This article presented a metric evaluation of automatically generated point clouds and mesh surfaces, based on UAS images acquired with a low-cost platform, i.e. DJI Phantom 3 Standard, using two different software with the capability of automatically orienting the images, Pix4D and 3DF Zephyr Pro. We also determined the optimum number of GCPs in order to georeference a block of nadiral UAS images, by processing the images with 3 GCPs, 4 GCPs, up to 40 GCPs, founding almost the same number for the 28 m and 35 m flight and for the two different software. We can conclude that in order to obtain high accuracy of the final products, a density of 1 GCP/200 m^2 is necessary.

The results expressed a clear overview on the number of GCPs needed for the indirect georeferencing process with minimum influence on the final results.

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Author Contributions: Ersilia Oniga and Ioana Breaban conceived and designed the experiments and analysed the data; Ersilia Oniga, Ioana Breaban and Florian Statescu performed the surveys and processed the measurements; Ersilia Oniga and Ioana Breaban wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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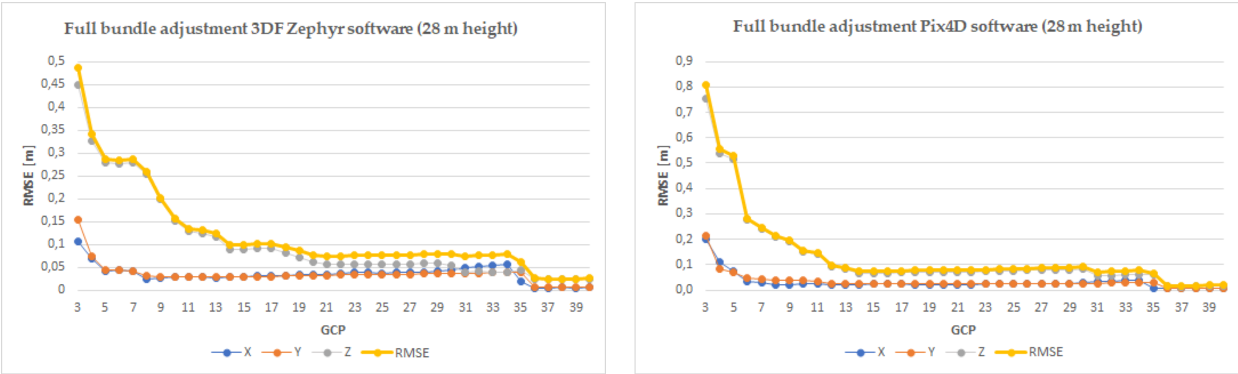
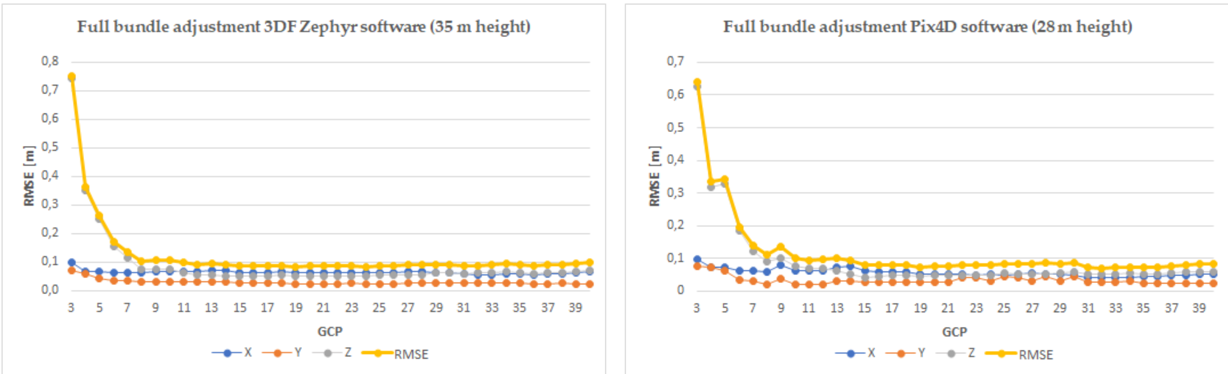
Appendix A



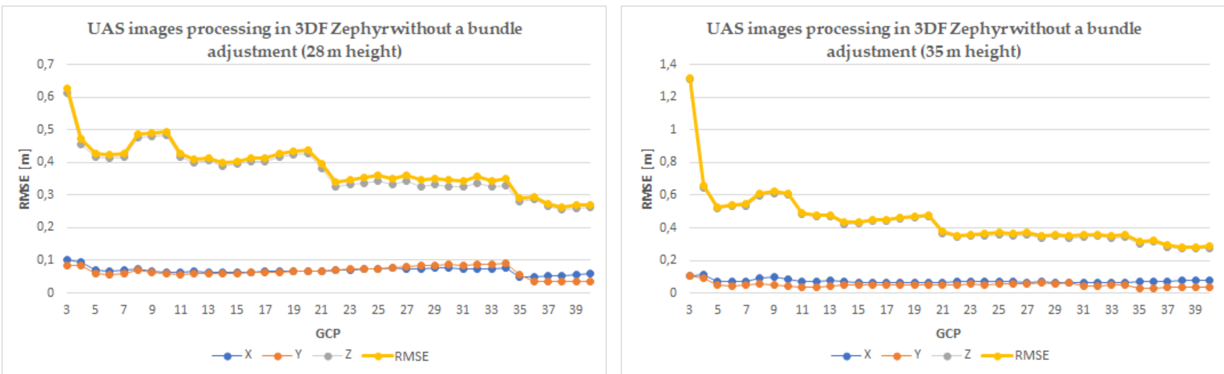
(a) (b)

Figure A1. Errors obtained for 28 m height when using 3 to 40 GCPs along x, y and z directions, as well as the RMSE performing a full bundle adjustment process (**a**) using Pix4D software, (**b**) using 3DF Zephyr Pro software.



(a) (b)

Figure A2. Errors obtained for 35 m height when using 3 to 40 GCPs along x, y and z directions, as well as the RMSE performing a full bundle adjustment process (a) using Pix4D software, (b) using 3DF Zephyr Pro software.

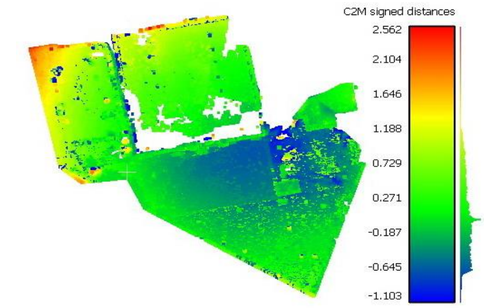
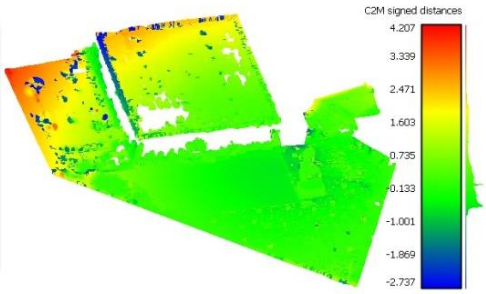


(a) (b)

Figure A3. Errors obtained by performing a Helmert transformation in 3DF Zephyr Pro sotware when using 3 to 40 GCPs along x, y and z directions, as well as the RMSE (a) for 28m flight, (b) for 35 m flight.

Appendix B

Table B1. The UAS point clouds generated in Pix4D and 3DF Zephyr software for the two flights and for the minimum and optimum number of ground control points.

<table>
<tr><th>3DF ZEPHYR PRO</th><th></th><th>PIX4D</th></tr>
<tr><td colspan="3">28 m heigh</td></tr>
<tr>
<td>
</td>
<td>Minimum GCPs:
3 Control Points
47 Check Points</td>
<td>
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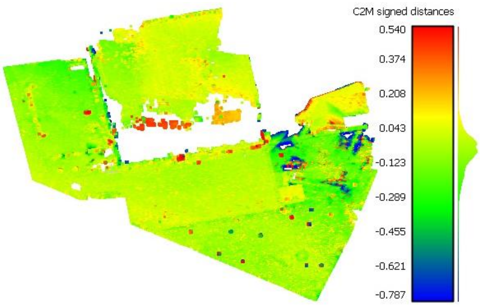
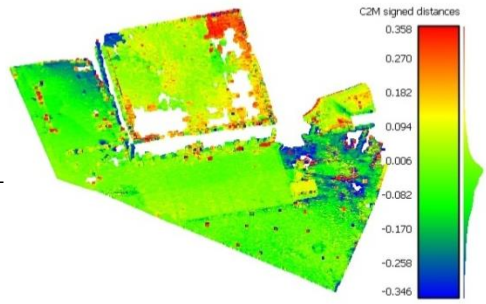
<td>
</td>
<td>Optimum GCPs:
3DF Zephyr Pro
20 Control Points
30 Check Points
Pix4D
14 Control Points
35 Check Points</td>
<td>
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</tr>
<tr><td colspan="3">35 m heigh</td></tr>
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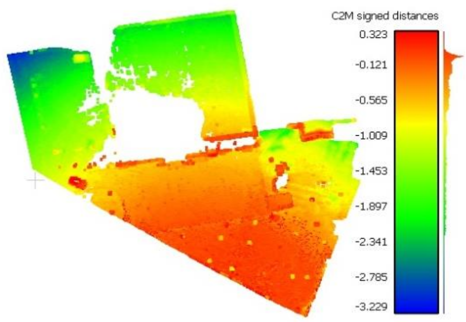
<td>
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<td>Minimum GCPs:
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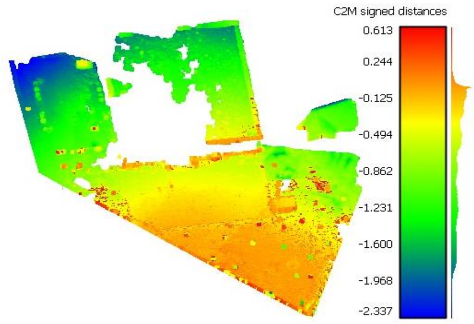
47 Check Points</td>
<td>
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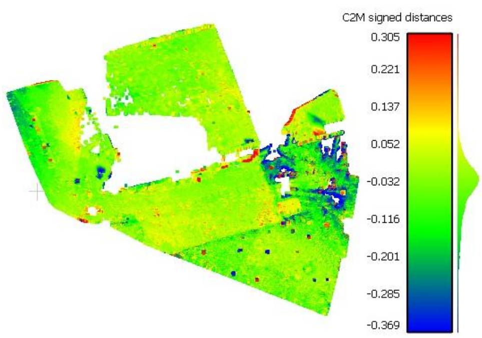
<td>
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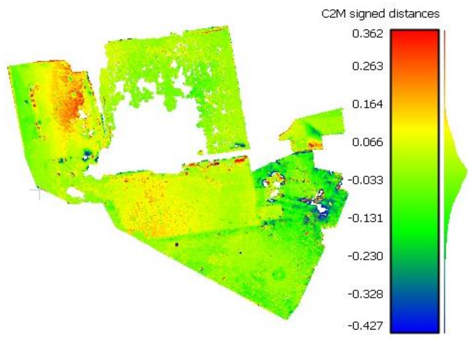
15 Control Points
35 Check Points</td>
<td>
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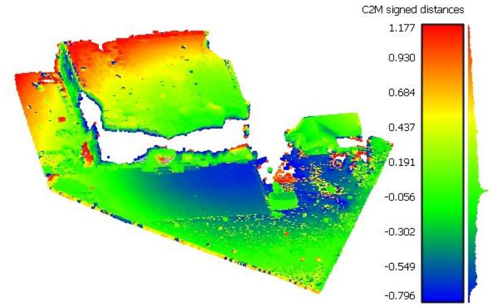
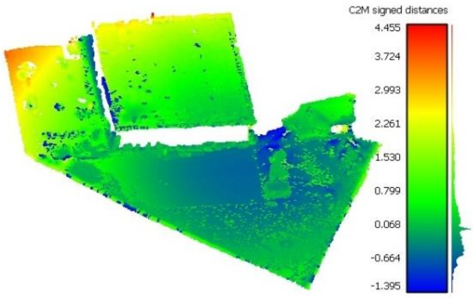
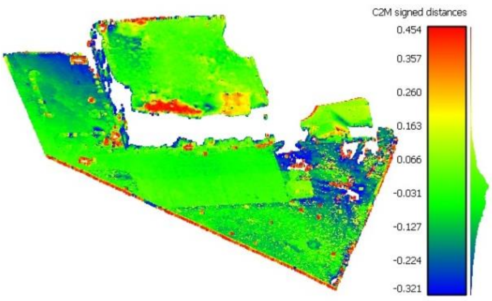
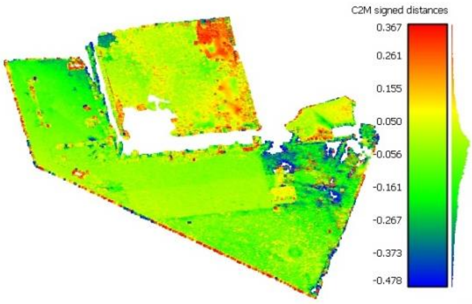
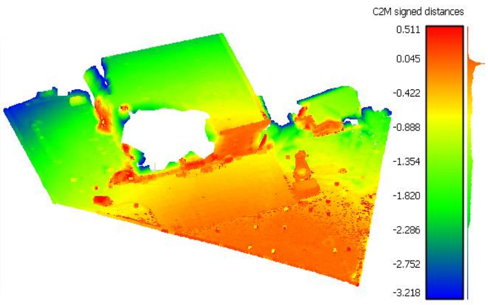
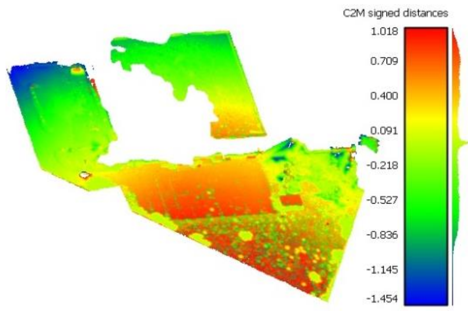
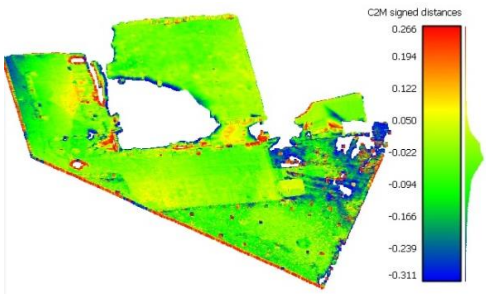
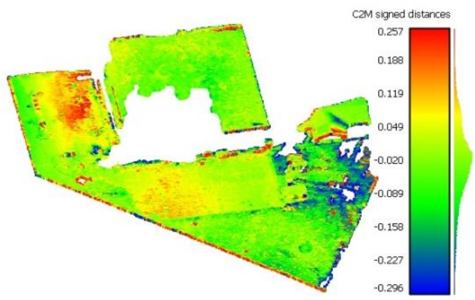
</tr>
</table>

Appendix C

Table C1. The mesh surfaces generated in Pix4D and 3DF Zephyr software for the two flights and for the minimum and optimum number of ground control points.

3DF ZEPHYR PRO		PIX4D
	28 m heigh	
	Minimum GCPs: 3 Control Points 47 Check Points	
	Optimum GCPs: **3DF Zephyr Pro** 20 Control Points 30 Check Points **Pix4D** 14 Control Points 35 Check Points	
	35 m heigh	
	Minimum GCPs: 3 Control Points 47 Check Points	
	Optimum GCPs: 15 Control Points 35 Check Points	

Appendix D

Table D1. Errors obtained for 28 m height along x, y and z directions, as well as the RMSE performing a full bundle adjustment process using 3DF Zephyr Pro and Pix4D software.

GCP	3DF ZEPHYR PRO				PIX4D				$RMSE_{3DF\ Zephyr}$ - $RMSE_{Pix4D}$ [m]
	28 m - RMSE [m]								
	X	Y	Z	RMSE	X	Y	Z	RMSE	
3	0,107	0,153	0,449	**0,486**	0,201	0,212	0,754	**0,809**	*-0,323*
4	0,069	0,073	0,325	**0,341**	0,108	0,084	0,539	**0,556**	*-0,215*
5	0,041	0,045	0,280	**0,287**	0,075	0,072	0,517	**0,528**	*-0,241*
6	0,043	0,044	0,277	**0,284**	0,035	0,047	0,277	**0,283**	*0,001*
7	0,042	0,042	0,279	**0,285**	0,031	0,043	0,241	**0,247**	*0,039*
8	0,023	0,031	0,255	**0,258**	0,020	0,036	0,210	**0,214**	*0,044*
9	0,027	0,030	0,198	**0,202**	0,021	0,038	0,192	**0,197**	*0,006*
10	0,029	0,029	0,151	**0,157**	0,023	0,036	0,149	**0,155**	*0,002*
11	0,028	0,029	0,128	**0,134**	0,024	0,033	0,141	**0,146**	*-0,012*
12	0,029	0,029	0,124	**0,131**	0,020	0,025	0,092	**0,097**	*0,033*
13	0,027	0,028	0,116	**0,123**	0,020	0,025	0,082	**0,088**	*0,035*
14	0,030	0,029	0,089	**0,099**	0,022	0,023	0,066	**0,074**	*0,025*
15	0,030	0,030	0,088	**0,098**	0,023	0,023	0,066	**0,074**	*0,024*
16	0,032	0,029	0,091	**0,101**	0,023	0,024	0,068	**0,075**	*0,025*
17	0,032	0,029	0,091	**0,101**	0,023	0,024	0,069	**0,076**	*0,024*
18	0,032	0,030	0,082	**0,094**	0,020	0,023	0,070	**0,077**	*0,017*
19	0,034	0,031	0,072	**0,085**	0,021	0,023	0,071	**0,078**	*0,008*
20	0,034	0,031	0,062	**0,077**	0,021	0,023	0,071	**0,078**	*0,000*
21	0,034	0,032	0,056	**0,073**	0,022	0,024	0,071	**0,078**	*-0,005*
22	0,036	0,034	0,056	**0,074**	0,022	0,024	0,072	**0,079**	*-0,005*
23	0,038	0,034	0,056	**0,076**	0,023	0,024	0,073	**0,080**	*-0,004*
24	0,039	0,034	0,055	**0,076**	0,023	0,025	0,074	**0,081**	*-0,006*
25	0,037	0,035	0,057	**0,076**	0,024	0,025	0,076	**0,083**	*-0,007*
26	0,039	0,034	0,057	**0,077**	0,024	0,025	0,077	**0,084**	*-0,007*
27	0,039	0,035	0,058	**0,078**	0,025	0,025	0,078	**0,086**	*-0,008*
28	0,040	0,036	0,059	**0,080**	0,025	0,026	0,080	**0,088**	*-0,008*
29	0,041	0,037	0,058	**0,080**	0,026	0,026	0,081	**0,089**	*-0,009*
30	0,044	0,037	0,054	**0,079**	0,027	0,027	0,082	**0,091**	*-0,012*
31	0,050	0,036	0,040	**0,074**	0,034	0,027	0,057	**0,071**	*0,002*
32	0,051	0,037	0,041	**0,076**	0,035	0,027	0,058	**0,073**	*0,002*
33	0,053	0,039	0,040	**0,077**	0,036	0,028	0,059	**0,075**	*0,002*
34	0,056	0,040	0,039	**0,079**	0,038	0,029	0,061	**0,077**	*0,002*
35	0,019	0,038	0,045	**0,062**	0,007	0,029	0,059	**0,066**	*-0,004*
36	0,005	0,007	0,024	**0,026**	0,005	0,005	0,014	**0,016**	*0,010*
37	0,005	0,006	0,023	**0,025**	0,005	0,005	0,013	**0,015**	*0,009*
38	0,005	0,006	0,024	**0,025**	0,005	0,006	0,016	**0,018**	*0,007*
39	0,005	0,005	0,024	**0,025**	0,006	0,007	0,017	**0,019**	*0,006*
40	0,005	0,006	0,024	**0,025**	0,006	0,007	0,018	**0,020**	*0,005*

Table D2. Errors obtained for 35 m height along x, y and z directions, as well as the RMSE performing a full bundle adjustment process using 3DF Zephyr Pro and Pix4D software.

GCP	3DF ZEPHYR PRO				PIX4D				$RMSE_{3DF\ Zephyr}$ - $RMSE_{Pix4D}$ [m]
	35 m - RMSE [m]								
	X	Y	Z	RMSE	X	Y	Z	RMSE	
3	0,101	0,069	0,743	**0,753**	0,099	0,078	0,627	**0,640**	*0,114*
4	0,068	0,058	0,352	**0,363**	0,074	0,073	0,319	**0,335**	*0,028*
5	0,068	0,045	0,250	**0,263**	0,073	0,061	0,328	**0,341**	*-0,078*
6	0,063	0,036	0,157	**0,173**	0,060	0,035	0,183	**0,196**	*-0,023*
7	0,063	0,033	0,114	**0,135**	0,063	0,031	0,122	**0,141**	*-0,006*
8	0,063	0,032	0,074	**0,102**	0,060	0,022	0,091	**0,112**	*-0,010*
9	0,065	0,032	0,076	**0,106**	0,078	0,037	0,102	**0,134**	*-0,028*
10	0,067	0,033	0,075	**0,106**	0,062	0,021	0,076	**0,100**	*0,006*
11	0,067	0,032	0,063	**0,097**	0,062	0,021	0,069	**0,095**	*0,002*
12	0,068	0,030	0,056	**0,093**	0,063	0,021	0,069	**0,096**	*-0,003*
13	0,073	0,030	0,055	**0,096**	0,074	0,032	0,062	**0,102**	*-0,006*
14	0,070	0,030	0,053	**0,093**	0,075	0,032	0,050	**0,095**	*-0,003*
15	0,064	0,028	0,053	**0,088**	0,062	0,027	0,040	**0,079**	*0,009*
16	0,064	0,028	0,052	**0,087**	0,058	0,026	0,046	**0,078**	*0,009*
17	0,064	0,027	0,053	**0,088**	0,058	0,027	0,047	**0,080**	*0,008*
18	0,066	0,027	0,054	**0,089**	0,059	0,028	0,047	**0,081**	*0,009*
19	0,062	0,025	0,049	**0,084**	0,052	0,026	0,045	**0,073**	*0,010*
20	0,064	0,025	0,052	**0,086**	0,052	0,027	0,047	**0,075**	*0,011*
21	0,064	0,025	0,052	**0,086**	0,053	0,027	0,047	**0,076**	*0,010*
22	0,064	0,025	0,052	**0,086**	0,051	0,041	0,047	**0,080**	*0,006*
23	0,063	0,026	0,053	**0,086**	0,048	0,042	0,049	**0,081**	*0,006*
24	0,061	0,025	0,053	**0,085**	0,053	0,030	0,049	**0,079**	*0,006*
25	0,063	0,024	0,055	**0,087**	0,049	0,043	0,054	**0,085**	*0,002*
26	0,065	0,024	0,056	**0,089**	0,050	0,042	0,050	**0,082**	*0,007*
27	0,066	0,025	0,057	**0,091**	0,057	0,032	0,050	**0,082**	*0,009*
28	0,067	0,026	0,057	**0,092**	0,052	0,044	0,052	**0,086**	*0,006*
29	0,062	0,026	0,062	**0,091**	0,053	0,032	0,056	**0,084**	*0,008*
30	0,063	0,026	0,062	**0,092**	0,047	0,044	0,057	**0,086**	*0,006*
31	0,058	0,027	0,061	**0,088**	0,042	0,027	0,051	**0,071**	*0,017*
32	0,057	0,028	0,062	**0,088**	0,040	0,027	0,050	**0,070**	*0,019*
33	0,057	0,028	0,063	**0,090**	0,041	0,028	0,052	**0,072**	*0,017*
34	0,060	0,029	0,066	**0,094**	0,042	0,029	0,054	**0,074**	*0,019*
35	0,059	0,026	0,065	**0,092**	0,045	0,024	0,053	**0,074**	*0,018*
36	0,057	0,024	0,061	**0,087**	0,045	0,023	0,053	**0,073**	*0,014*
37	0,059	0,025	0,064	**0,091**	0,047	0,023	0,055	**0,076**	*0,015*
38	0,061	0,026	0,064	**0,092**	0,049	0,024	0,057	**0,079**	*0,013*
39	0,064	0,023	0,068	**0,096**	0,050	0,023	0,060	**0,082**	*0,014*
40	0,067	0,024	0,071	**0,100**	0,052	0,025	0,060	**0,083**	*0,017*