Generating highly accurate 3D data using a senseFly albris drone

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Abstract

Professional drones (or UAVs/UAS) are now commonplace in land surveying, being used around the world for projects such as feasibility studies, construction monitoring, transport planning, cartographic mapping, cadastre, mine surveys and more. Today, drones are increasingly replacing the collection of geospatial point data by terrestrial GNSS base stations, however to date the absolute geospatial accuracy of drone-sourced 3D point clouds has not been proven to match the accuracy achievable with total stations.

This article presents the results of a project in which the senseFly albris close mapping and inspection drone was used to conduct a photogrammetric land survey of a construction site, using ground control points (GCPs). For this project, two albris were deployed on two separate missions to acquire 2D high-resolution images at 2 mm ground sampling distance (GSD). Each flight's images were then used to generate a 3D point cloud using Postflight Terra 3D (Pix4Dmapper-powered image processing software).

The results show that 3D point clouds produced with an albris quadcopter can reach a global precision comparable to a typical total station survey and, as such, meet the typical accuracy requirements of construction projects.

An additional benefit of using an albris drone for such a survey is the higher point density of the data set produced.

Introduction

While professional drones are today commonly used in land surveying and GIS applications, it is unusual to see them employed on construction sites for highly accurate survey work. The senseFly albris close mapping and inspection drone was developed to achieve the kind of accuracy capable of changing this. Lehmann Géomètre SA (www.geomatique.ch) invited senseFly engineers to a construction site that the company is responsible for regularly monitoring.

A total station was used to set the necessary GCPs and to measure check points. (Very precise GCPs are required to target highly accurate results from such a drone flight.)

Due to the site's relatively small size, acquiring images of the entire site required only a single drone flight. Nevertheless this flight was repeated with a second albris drone in order to demonstrate the repeatability of the results.

For practical reasons, the flights were flown after construction staff had left the site, at the end of the working day. This timing resulted in less than ideal image acquisition conditions with relatively low light and lots of shadows.

The coordinate system used for the entire project was CH1903/LV03 with orthometric heights (geoid model CHGeo04).

Figure 1 – The construction site.

The site

The construction site surveyed is situated in Chailly-sur-Lausanne, Switzerland (figure 1). The site is owned by Association le Foyer, an educational centre for the blind and people with intellectual disabilities.

This site presents a complex environment, with trees and buildings situated around the perimeter and, at the time of the project, one crane also on-site.

About albris

The senseFly albris is an intelligent rotary drone designed for close mapping and industrial inspection applications. It is equipped with an autopilot and GPS. It features a fully stabilised TripleView (HD video, 38 MP still, thermal) camera head, five navcam sensors and five ultrasonic proximity sensors. Thanks to the situational awareness provided by this array of sensors the albris can fly close to objects in order achieve submillimeter GSDs.

At low altitudes, or when flying close to objects, the albris is best operated in its Interactive ScreenFly mode. This includes features such as Cruise Control, Distance Lock and the auto-triggering of images. For safety of operation the albris is lightweight, fully shrouded and features multiple safety functionalities.

Methodology

Measuring GCPs and Check Points

The project featured 5 GCPs (100-500) and five Control points (700-1100), distributed across the construction site (*figure 2*), with up to 1.39 m altitude difference between them.

The positions of those points were measured precisely with a Trimble S6 2 DR 300+ total station. In order to maximise the accuracy of these measurements, small reflective targets were used (*figure 3*), positioned vertically on the point of each coloured marker, rather than prisms.

The accuracy of the 10 marked points measured on the site was 2 mm horizontal (XY) and 2 mm vertical (Z).

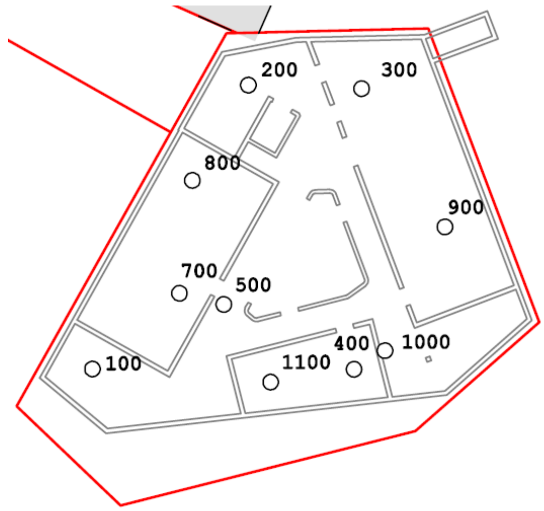

Figure 2 – Map of the ten target positions around the site (in the later processing, numbers 100-500 were marked as GCPs, and 700-1100 were designated as check points).

Figure 3 – A small reflective target was used to measure the ten marker locations with the total station.

Drone Flights & Settings

The albris camera used to capture aerial images was the drone's main still camera. Located within the drone's TripleView head, this sensor features a resolution of 38 megapixels. The flight planning and control software used was senseFly's eMotion X 1.0, while the post-flight photogrammetry software employed was Postflight Terra 3D 4.0 (powered by Pix4D).

The flight was conducted at constant height of 14 m above the terrain (*figure 4*), which led to the achieved average GSD of 2.2 mm. The drone was operated in Interactive ScreenFly mode, whereby the drone is controlled using a handheld ScreenFly controller connected to eMotion X. After take-off, the albris climbed to 14 m, which it maintained during the entire flight. albris Cruise Control (set at 0.5 m/s) and its Auto-Trigger function (set to capture one image every 5 s) were used to complete the project in a single flight.

During the first albris flight six flight lines were used to capture 108 photos. The second albris flight was completed in 7 flight lines and captured 133 photos.

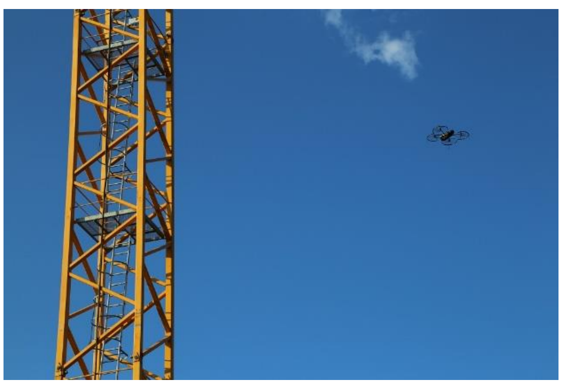

Figure 4 – The albris flew at an altitude of 14 m above the take-off point.

The on-site crane and surrounding trees presented a challenge, therefore the on-screen footage from the drone's five different navcams, plus its ultrasonic proximity sensors' readings, was helpful to ensure no contact was made.

Following the two flights, the captured raw (DNG) image files were imported into eMotion X's Flight Data Manager, where they were automatically converted into high-quality JPEG images and geotagged with data from the drone's BBX format flight log.

Both flights were treated as independent projects in Postflight Terra 3D, and processed independently to transform each flight's images into a 3D point cloud. The previously measured GCPs and check points were also input into Postflight Terra 3D.

The software's rayCloud Editor was then used to locate each of the ten points in the point cloud (*figure 5*). Five of these points, the black and white coloured targets, were marked in the software as GCPs and used to re-optimise the project. The remaining five red and black targets were marked as check points and as such served to control the project's accuracy.

Figure 5 – GCP 400, visible in 18 different images.

Results

The results achieved show high positional accuracy throughout the point cloud. This is due to the high resolution and sharpness of the flight's images, and the quality of Postflight Terra 3D's processing engine.

GCPs

As shown in the GCP tables of figures 6 and 7, the positioning of the point cloud on the GCPs was highly accurate for both flights, with less than one millimeter RMS error. Projection errors were also low confirming that, amongst other factors, the GCPs were correctly marked in Postflight Terra 3D's rayCloud Editor.

GCP	Error			Projection Error (pixel)
	X (m)	Y (m)	Z (m)	
100	0.000	0.000	0.001	0.011
200	0.001	-0.001	-0.001	0.066
300	-0.000	0.001	0.001	0.047
400	-0.001	-0.000	-0.000	0.067
500	-0.000	-0.001	-0.000	0.010
Mean (m)	0.000022	-0.000008	-0.000118	
Sigma (m)	0.000476	0.000812	0.000803	
RMS (m)	0.000476	0.000812	0.000811	

Figure 6 –GCP results for flight 1, taken from Postflight Terra 3D's Quality Report.

GCP	Error			Projection Error (pixel)
	X (m)	Y (m)	Z (m)	
100	-0.000	-0.001	0.001	0.006
200	0.001	-0.000	-0.003	0.007
300	-0.000	0.000	0.003	0.042
400	-0.001	0.000	-0.001	0.028
500	0.000	0.000	0.000	0.048
Mean (m)	-0.000039	0.000041	0.000013	
Sigma (m)	0.000415	0.000382	0.002148	
RMS (m)	0.000417	0.000384	0.002148	

Figure 7 – GCP results for flight 2, taken from Postflight Terra 3D's Quality Report.

Check Points

Regarding the project's five check points, the accuracy results of the two flights were both within planimetry and altimetry expectations.

The first albris flight (figure 8) achieved 2.1 mm accuracy in X, 1.9 mm in Y and 0.1 mm in Z (RMSE). The second albris flight (figure 9) achieved 0.8 mm (X), 0.5 mm (Y) and 4.2 mm (Z).

The accuracy achieved was due, in part, to the high relative accuracy of the GCPs, and in part due to the excellent reoptimisation achieved by Postflight Terra 3D. The software's optimisation of internal camera parameters, especially focal length, was successful as the maximum depth error (Z axis in this case) for both flights was just 6.1 mm, which falls easily within the range of acceptance for a project such as this.

Also helpful was the even placement of the GCPs around the site.

Check point	Error			Projection Error (pixel)
	X (m)	Y (m)	Z (m)	
700	-0.0003	-0.0007	0.0001	0.2540
800	0.0005	-0.0028	-0.0002	0.2143
900	0.0045	0.0030	0.0001	0.2875
1000	0.0004	-0.0007	-0.0001	0.3272
1100	-0.0015	0.0005	-0.0001	0.3081
Mean (m)	0.000712	-0.000146	0.000046	
Sigma (m)	0.002007	0.001902	0.000096	
RMS (m)	0.002130	0.001908	0.000106	

Figure 8 – Check point results for flight 1, taken from Postflight Terra 3D's Quality Report.

Check point	Error			Projection Error (pixel)
	X (m)	Y (m)	Z (m)	
700	0.0003	0.0002	-0.0061	0.1962
800	0.0003	-0.0003	-0.0048	0.2103
900	0.0011	0.0003	0.0013	0.1765
1000	-0.0011	-0.0010	-0.0053	0.2704
1100	-0.0010	-0.0004	-0.0003	0.3256
Mean (m)	-0.000072	-0.000334	-0.003023	
Sigma (m)	0.000818	0.000415	0.002945	
RMS (m)	0.000821	0.000533	0.004220	

Figure 9 – Check point results for flight 2, taken from Postflight Terra 3D's Quality Report.

Conclusions

Even flying in low-light conditions, the albris survey produced a 3D point cloud (*figures 10 and 11*) of millimetre accuracy, equivalent to the accuracy achievable using a total station.

The albris solution is therefore proved to be a high performance surveying instrument, capable of fitting into existing surveying workflows.

Since this project's two flights took place at an altitude of 14 m above take-off, we can assume that using a lower altitude could, potentially, improve positional accuracy still further.

Additionally, albris-produced point clouds provide an extraordinary density of points and additional information, such as texture. The point cloud produced following flight 2 of this project, for example, features approximately 20,000,000 data points.

Postflight Terra 3D also outputs other files, which include a triangulated irregular network (TIN, called a 'mesh' in Postflight).

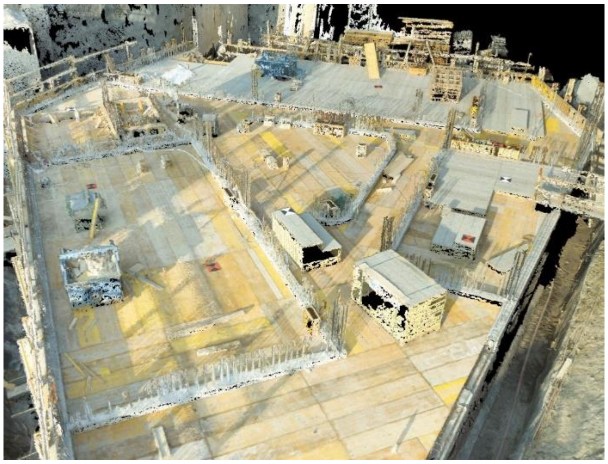

Figure 10 – Densified 3D point cloud (flight 1).

Figure 11 – A close-up of the same densified 3D point cloud with one GCP (black & white) and two check points (red & black) visible.

Project Statistics

	Flight 1	**Flight 2**
Area covered (point cloud)	1,186 m^2 (0.12 ha/0.29 ac/12,766 ft^2)	1,133 m^2 (0.11 ha/0.28 ac/12,195 ft^2)
Flight time	13 min	13 min
Altitude ATO	14 m (46 ft)	14 m (46 ft)
Avg. GSD	0.22 cm (0.09 in)	0.22 cm (0.09 in)

Contact

For more information on this project, please contact senseFly at info@sensefly.com or call +41 21 552 04 40.