WHITE PAPER STORMBEE S20

1. Goal of the study

This study aims to compare classical topographic survey results with the typical point cloud delivered by the STORMBEE RPAS. The difference is treated in methodological and statistical approaches.

A topographical building survey by GNSS and total station delivers pre-interpreted results to the end-user. What the surveyor has measured on the terrain, is what will eventually will be present in the user's data asset database. In many cases 2D en 3D deliverables are delivered and/or measured separately unless the customer specified this beforehand. In practice this means that the top view 2D building outline might be measured at the same time of a digital terrain model (DTM). While 3D coordinates of the building points are available from the measured data, they are stripped from the end product. Similarly 3D topographical measurement of building facades are usually measured in 3D coordinates, but presented in the 2D coordinate system that best fits the vertical plane of the façade. This means that any point missing in the survey data requires reconstruction from other sources of data (less accurate) or going back to the job site.

2D building overlay on aerial picture (source: Geopunt)

With terrestrial laser scanning this problem is partly solved by capturing millions of points, allowing the surveyor to measure any point in the step of post processing the point cloud. 3D coordinates of measured points and lines are easily maintained in the process. Rooflines are measured similar as with traditional survey methods, and the roof surface is not directly measured.

Airborne laser scanning from airplanes can deliver roof surfaces, but generally lack the spatial resolution comparable to terrestrial surveys and is limited to mostly vertical scanlines. Airborne laser scanning from an RPAS platform is more versatile in scanning angle and distance to the scanned object. These platform can deliver a single survey solution for large scale asset management spatial data requirements.

2. Methodology

A simultaneous survey of the STORMBEE S20 test site in Ghent was carried out in the fall of 2018. The same buildings and site assets were measured in the time period of 10 am – 2 pm to ensure an identical or at least a very similar GNSS satellite constellation. The test site is a 2 hectares agricultural plant near Ghent with several warehouse type buildings.

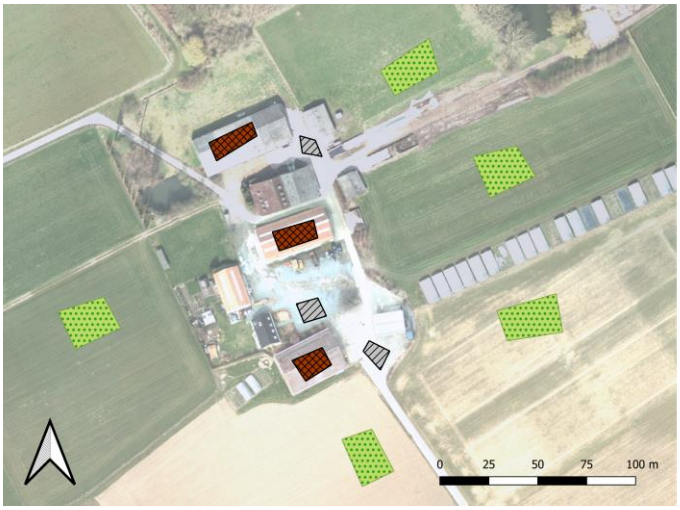

The 2 ha site near Ghent.

In a topographic survey with total station and GNSS all buildings were measured. Characteristic shape points of the building outlines and roof structures were measured in 3D coordinates. Spread out over the site ground targets were placed to ensure geographical matching between the topographic survey and the dataset from the STORMBEE RPAS.

The coordinate match of both surveys allows for an easier selection of identical features in both datasets. This reduces the risk of falsely identifying the features in both datasets. Every point in the topographic survey can be matched with the closest point from the STORMBEE point cloud.

Because the point cloud is richer in information, a point-by-point analysis is not sufficient. Cross-profiles generated from the topographic survey are also compared with the point cloud.

Before analysis, the internal consistency in the STORMBEE dataset was analysed over different flights and cross referenced with different land cover types (grass, building, concrete).



The different patches of landcover type used in the analysis of the variance between point clouds from different flights.

3. Fieldwork & postprocessing

3.1 Summary

Drone	STORMBEE S20
Scanner	FARO S350
Date of flight	15th November, 2018
Altitude	15m
Flight speed	4 m/s
Conditions	Light winds, sunny, 9-14°C
Faro settings	Resolution 1/5, Quality factor 2 (default settings)
Base station	Trimble SPS585 Smart Target Antenna

3.2 Trajectory

Trajectory of the test flights exported from POSPac to Google Earth.

Three test flights were conducted following the same, programmed trajectory as shown in fig 4. The flight speed and scanner settings were identical for each flight. Base station data was simultaneously and continuously recorded throughout the tests using the Trimble SPS585 Smart Target Antenna.

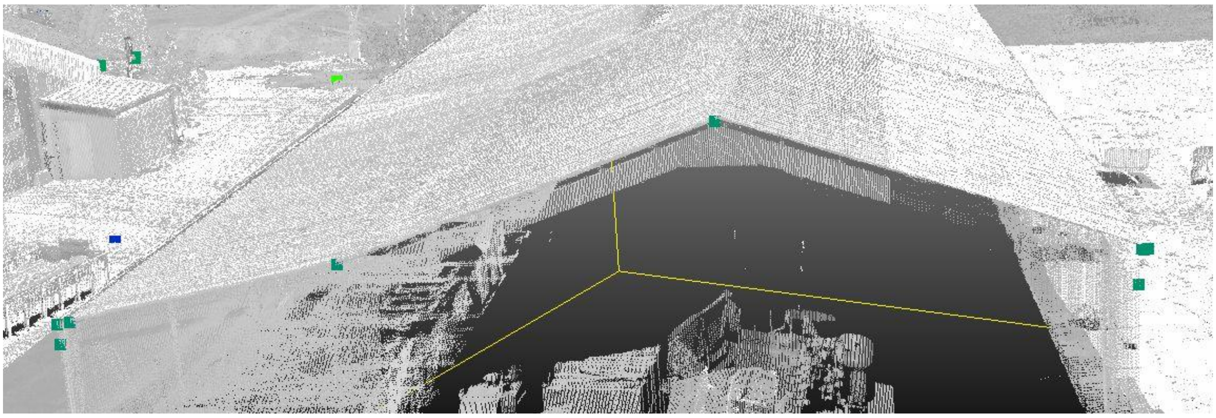
After completion of the flights, the SD card was removed from the scanner and the raw scan data was downloaded as an .fls file. The raw GNSS data was downloaded using the FTP application Filezilla. We downloaded the base station data directly from the Trimble SGS585.

4. Topographic Survey

A Trimble VX total station and a Trimble R8s GNSS device were used to conduct the topographic survey with integrated survey methods. The RTK survey on the FLEPOS network delivers 1-2 cm accuracy on the station setup for the total station. Whenever possible, a GNSS RTK measurement with 5 observations was done for terrain points. For facade points a reflectorless measurement was carried out by manual sighting on pre-identified points. Surveyed façade points include: gutters, start of roof, roof line points, ridge points.

Special care was taken that the GCPs were not occupied with the GNSS during flight.

The topographic survey was processed as normal with a 2D output in UTM coordin and 3D drawings of the building facades.

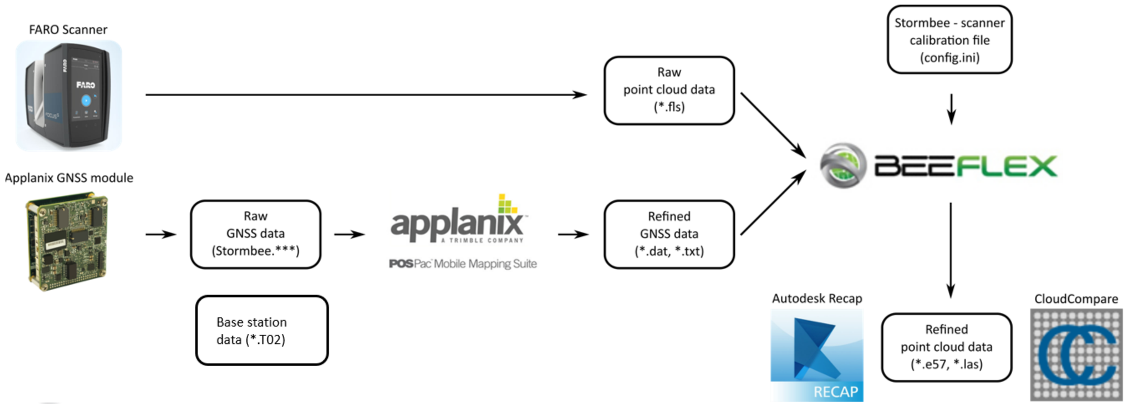


Detail of surveyed points on an open wall warehouse facility.

5. Postprocessing Stormbee data

The data was postprocessed using two separate applications, POSPac from Applanix and BEEFLEX, the in-house software supplied as part of the STORMBEE drone package.

POSPac was used to combine the raw GNSS data with data collected from the Trimble SGS585 base station to produce a refined, more accurate trajectory. This refined trajectory was then synchronized automatically in BEEFLEX with the scan data to produce the point cloud. A scanner calibration file was also linked to ensure an accurate projection.

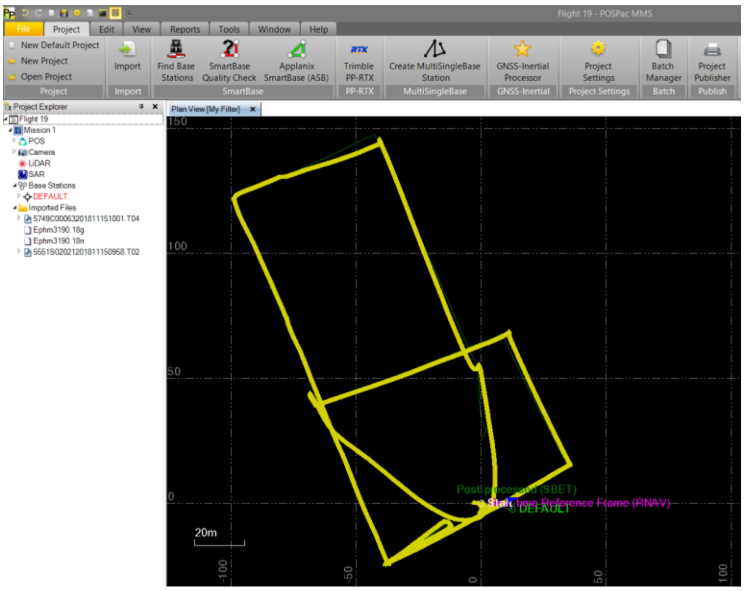


Postprocessing workflow.

5.1 Pospac

The trajectory was processed using the T02 and T04 files downloaded from the Trimble SGS585 base station and the STORMBEE S20 respectively. The two files were simply dragged in to the screen of the user interface and the built-in GNSS processor was activated to produce the refined trajectory. This refined trajectory is shown in the figure below as the fine green line. The yellow trajectory is the raw trajectory.

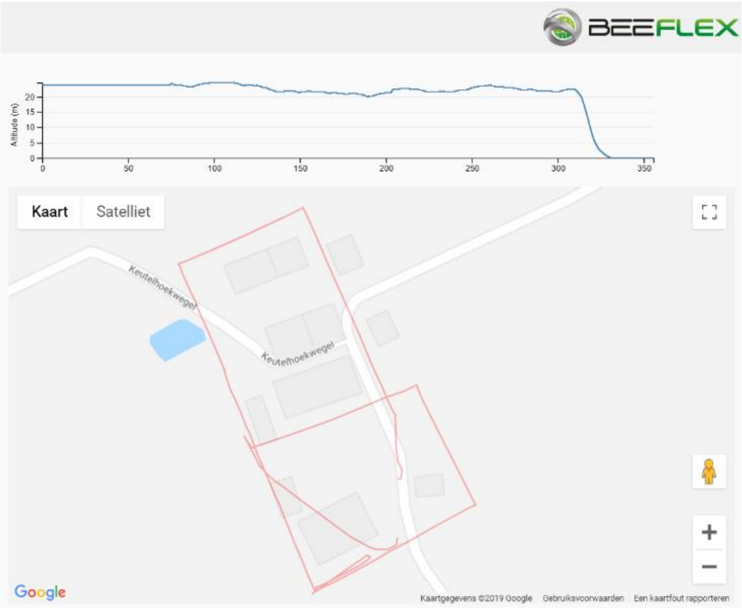
The result was then exported and the resulting .dat and .txt files were copied to a folder ready to be processed in BEEFLEX.



Refined trajectory in POSPac.

5.2 Beeflex

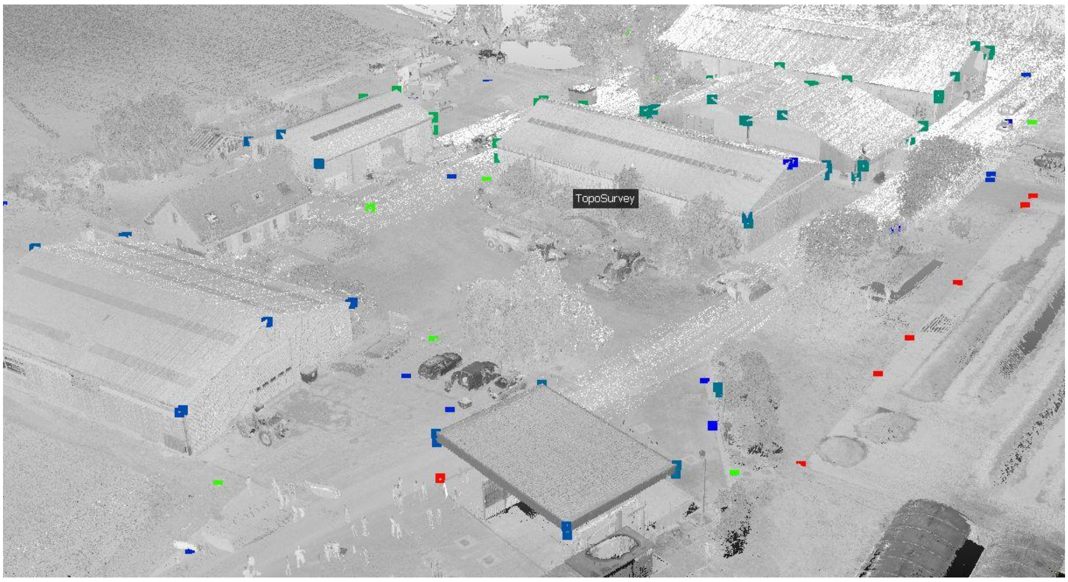
The raw scan data in .fls format was then copied to same folder as the files exported from POSPac, along with the calibration file. BEEFLEX was then linked to the folder file path and the software automatically processed the files to create the point cloud.



6. Point cloud Analysis

6.1 Visual analysis

An initial visual analysis shows no large discrepancies between both surveys when overlaid. One corner of the gas station in the southeast corner shows a small gap in the ALS data. This is due to nearby trees that obstruct the line of sight between the STORMBEE and the structure. This point will be left out of the analysis, as it would not be an issue for modeling purposes.



A full overview of the airborne laser scan point cloud, overlaid with the points from the topographic survey.

6.2 Point cloud consistency

This step was necessary to exclude that any difference between the STORMBEE data and the topographic survey would be caused by variations between the different flights of the STORMBEE. This analysis was carried out on 11 patches of homogeneous surface (grass, concrete and roof). For every patch the average distance from one point cloud to the mesh of every other point cloud was calculated.

For a complete comparison a more extensive study would be necessary. Since the application of laser scanning as such is not part of this study, this was not treated here. The results show that any variance within the point cloud from one flight, cannot be distinguished from the variance between point clouds from different flights.

Comparison of Euclidean distance between the point clouds from separate flights (numbered 19, 20, 21) to the meshes generated from all other flights. The meshes are calculated using a 2.5D Delaunay triangulation with a one meter threshold. The table shows the difference for each combination with the standard deviation shown between brackets.

OVERALL (m)				
		MESH		
		19	20	21
Point cloud	19	X	0.015 (0.033)	-0.018 (0.265)
	20	-0.015 (0.085)	X	0.034 (0.062)
	21	0.018 (0.0623)	0.035 (0.0374)	X

These tables show the overall comparison, split up between three different land cover types. Five patches of grass and three patches of roof and concrete each.

GRASS (m) n = 5				
		MESH		
		19	20	21
Point cloud	19	X	0.006 (0.055)	-0.018 (0.042)
	20	-0.001 (0.191)	X	-0.031 (0.046)
	21	0.019 (0.117)	0.026 (0.043)	X

ROOF (m) n = 3				
		MESH		
		19	20	21
Point cloud	19	X	0.009 (0.020)	-0.010 (0.017)
	20	-0.012 (0.035)	X	-0.023 (0.028)
	21	0.012 (0.047)	0.025 (0.035)	X

CONCRETE (m) n = 3				
		MESH		
		19	20	21
Point cloud	19	X	0.019 (0.027)	0.018 (0.027)
	20	-0.012 (0.106)	X	-0.033 (0.111)
	21	0.018 (0.042)	0.035 (0.036)	X

Further analysis of the variance (ANOVA) of the three flights shows that with a p-value of 0.95 the difference between the point clouds of subsequent flights is not statistically significant.

6.3 Point by point analysis

For every topographic measured point, the nearest feature in the point cloud was identified to calculate the distance. The differences observed here are caused by the sighting errors in the topographic survey and the density and resolution of the ALS data.

The average of 2D and 3D distances are well within limits. The larger difference for the gas station is due to the missing part in the point cloud and not due to an error in measurement in either dataset.

The standard deviation in Z in for the wall points are less relevant, as these are measured at a random point on the wall corner in the topographic survey. The 2D coordinates are within measurement limits for these points.

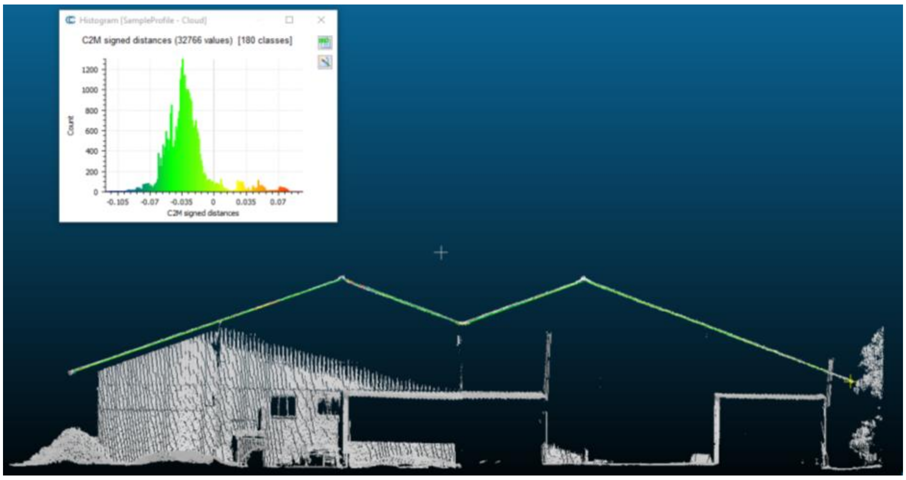
Table of average 2D and 3D distances between surveyed points and the closest point cloud point.

Type	Count	Average of 2D	Average of 3D
gutter	33	0,048	0,062
ridge	21	0,045	0,058
gas station	7	0,039	0,083
roof point	18	0,046	0,069
wall	13	0,034	0,078
Eindtotaal	**92**	**0,044**	**0,066**

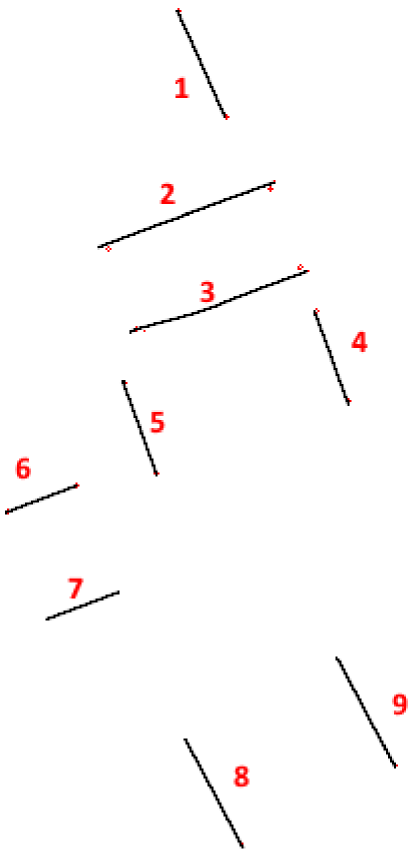
This analysis gives a basic idea of the accuracy of the lasers canning point cloud with reference to a topographic survey, but it does not take into account the total amount of points that are available in the point cloud. As such, these numbers rather give an upper limit of the accuracy instead of an actual value.

6.4 Cross-profile analysis

Although the point by point analysis shows promising results, analysis of the derived product was carried out. The building profiles as derived from the topographic survey were drawn in 3D instead of the traditional 2D façade measurement drawing. The single lines were joined together in CAD and divided into points. This simulates the topographic survey as a point cloud and allows for a similar analysis as in the point cloud consistency part. The ALS point-cloud was reduced to the part that corresponds with the topographically measured profile. For the facade shown in this example, the average difference between both datasets is -0.030 meter with a standard deviation of 0.026 meter.



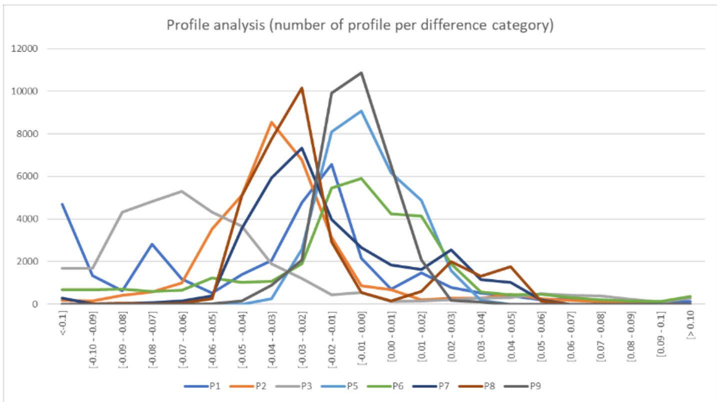
This analysis was performed for 9 building profiles. The fourth profile was excluded because of a missing point in the topographic survey, causing a shift over the vertical axis on one corner of the building.



Overview of the 9 profiles. Profile 4 was excluded because of a clear error in the topographic survey product.

The mean difference for the 8 processed profiles is -0.022 meters, with a standard deviation of 0.036 meters. The following table and graph shows the numbers and distribution per profile. In practice this means that the topographical survey is slightly below the similar product derived from the STORMBEE point cloud.

Stats	P1	P2	P3	P5	P6	P7	P8	P9
MEAN	-0,038	-0,032	-0,054	-0,003	-0,009	-0,015	-0,019	-0,007
STD	0,046	0,026	0,043	0,013	0,039	0,029	0,026	0,011



7. Conclusion

- Given the measurement accuracy of the topograhic reference data used in this comparison, the expected accuracy of the STORMBEE point cloud is within the range of 2 to 3 centimeters.
- The accuracy of the STORMBEE point cloud products holds up in comparison with traditional survey methods.
- When needed the accuracy of the STORMBEE point cloud could be increased, but this will most likely come with lower productivity (more flights). The largest gain is to be expected from flying slower.

Improving the accuracy of the ALS data:

For Z: fly lower (better spatial resolution in the point cloud)

For X,Y: fly slower (scan lines closer to each other)

8. Glossary

DTM	Digital Terrain Model
DSM	Digital Surface Model
GNSS	Global Navigation Satellite System
FLEPOS	Flemish Positioning System
RTK	Real Time Kinematic
ALS	Airborne Laser Scanning
CAD	Computer Aided Drawing

In collaboration with *Dennis Devriendt, lecturer HOGENT, Department of Real Estate and Applied Geomatics as Author and Malcolm McGinn, Senior Application System Engineer at STORMBEE as co-author.*

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UNBEATABLE ACCURACY IN MOBILE 3D LASERSCANNING