WingtraOne PPK Accuracy

Yi Hao Ng[1], Jakob Buchheim[2]

Abstract

High accuracy aerial mapping is crucial for demanding applications in surveying industry. Ultra precise georeferencing of aerial images with the help of GPS correction technology opens up the opportunity for extremely efficient data acquisition by drones. WingtraOne PPK system defines the new state-of-the-art in accurate aerial data acquisition. With setup time of less than 8 min, WingtraOne RX1 PPK covers the area of interest and yields ultra high image quality and resolution. Moreover, WingtraOne RX1 PPK is capable of highly accurate georeferencing based on advanced post process kinematic (PPK) GPS correction solution. WingtraOne RX1 PPK is capable of producing aerial imagery with ground sampling distance down to 0.7 cm/px and an unprecedented absolute accuracy of 1.3 cm in horizontal and 2.3 cm in vertical direction (RMS error) without the need of Ground Control Points (GCPs). Besides that, WingtraOne RX1 PPK also performs tremendously well in terms of relative accuracy by completing a volume measurement with an error of only 2.7 %. This extraordinary accuracy on single pixel level constitutes the new top-class aerial mapping solution for precision surveying applications.

Introduction

In the world of drone mapping, accuracy has always been a hot topic for professional surveyors. Accuracy for drone maps can be categorized into relative accuracy and absolute accuracy. Both relative and absolute accuracy of the orthophotos and other outputs are very important depending on the application and goal of the project.

For applications which involve measurements, inspections, and monitoring, relative accuracy is usually sufficient. On the other hand, absolute accuracy is necessary if a high degree of confidence in GPS coordinates measurements is needed. Examples for such application include land title surveys, environmental records, site plan overlays and so on.

The momentous advancement in drone technology over the past few years has also enhanced the ability for drone maps to be highly accurate, even without the need of Ground Control Points (GCPs). Amid the fierce competition between professional surveying drones for the most accurate and efficient mapping technology, this report shows that the WingtraOne PPK system (FIGURE 1 i) offered by Wingtra has successfully set a new benchmark for accuracy in the world of surveying drones.

With both the high-end PPK technology (FIGURE 1 ii) and the professional-grade camera integrated in the WingtraOne PPK, the drone is capable of delivering the best orthophoto accuracy together with the top quality images to surveyors. On top of that, the simple workflow of WingtraOne PPK defines a new level of efficiency in high accuracy drone mapping.

[1] Customer Success Engineer, Wingtra AG, Giesshübelstrasse 40, 8045 Zürich, yihao.ng@wingtra.com
[2] Project Engineer, Wingtra AG, Giesshübelstrasse 40, 8045 Zürich, jakob.buchheim@wingtra.com

FIGURE 1: i) Top-view on WingtraOne RX1 PPK tail sitter VTOL drone. ii) High precision WingtraOne PPK module. Available as an add-on to PPK ready WingtraOne units.

Methodology

Test Site

As the testing site to evaluate the WingtraOne PPK accuracy, a gravel quarry with the size of around 15 Ha was chosen, which is located in the north of Zürich, Switzerland.

Reference Data

Ten high precision verification points (FIGURE 2) were distributed in the testing site in the region of interest (FIGURE 3). A Trimble R8 GNSS receiver was used to determine the coordinates of these verification points. The GNSS receiver takes corrections from swisstopo's Automated GNSS Network for Switzerland (AGNES), which yields accuracy of 5 mm / 10 mm (horizontal / vertical).

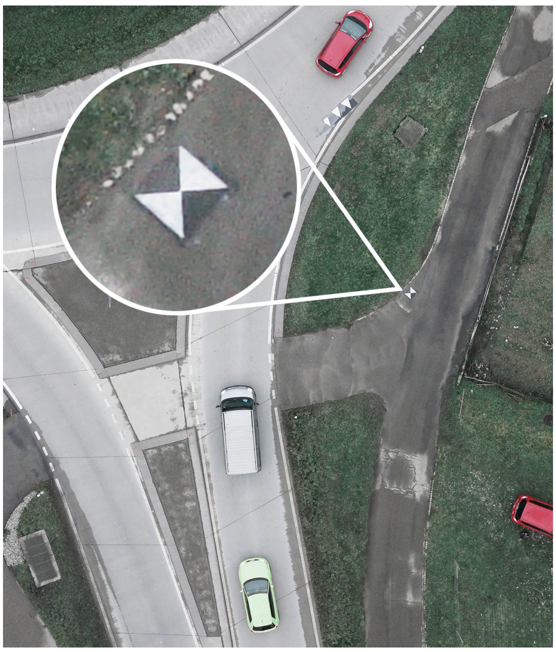

FIGURE 2: Aerial image shows one of the ten verification points distributed on the test site. The inset exhibits the high resolution imagery acquired by WingtraOne RX1 PPK.

Flight details

Three flights were flown over the test site with the WingtraOne RX1 PPK system (TABLE 1). All flights were conducted on the same day and therefore have comparable weather (no precipitation, 5°C ambient temperature, wind speed ~3 m/s) and light condition (cloud coverage $EV_{100} > 11.5$). The VTOL drone WingtraOne RX1 PPK is equipped with a high-end full frame 42 MP Sony RX1 Mark II camera. The sophisticated optics of the 35 mm lens warranties the best in class aerial photography through ultra low geometric distortions and negligible chromatic aberration. Camera settings were 1/2000 s shutter speed, FN4.5 and auto ISO, resulting in aerial images with ~18 MB size and ISO ranging from 1000 - 2500. Flight altitude above home was 70 m which defined the ground sampling distance (GSD) to ~0.9 cm/px.

Flight no.	1	2	3
Average GSD	0.97 cm/px	0.97 cm/px	0.96 cm/px
Side overlap	70 %	70 %	75 %
Front overlap	70 %	70 %	80 %
Area covered	25.56 ha	25.56 ha	18.29 ha
Number of images	984	984	1231
Flight time	18 min 56 s	18 min 55 s	17 min 26 s
Setup time	7 min	5 min	5 min

TABLE 1: Flight details of WingtraOne RX1 PPK

Georeferencing

After the completion of the three flights, a single SD card containing the images and the PPK log files was retrieved from the WingtraOne RX1 PPK. As for base station data, a RINEX log file (1 s temporal resolution) from a CORS (Continuously Operating Reference Station) was used, which is provided by swisstopo (location: Schaffhausen SCHA, in cartesian coordinates, WGS84, ellipsoidal height). Using the images, PPK logs from the SD card, and the reference station data and location, WingtraHub software was used to compute the accurate geolocation of every single image and store it in the GPS EXIF image tag (in WGS84 with ellipsoidal height).

Post-processing

The georeferenced aerial images were post-processed using Pix4Dmapper Pro 4.1.24 (Pix4D)[3] to generate a point cloud and an orthomosaic (FIGURE 3) out of the individual images of each flight.

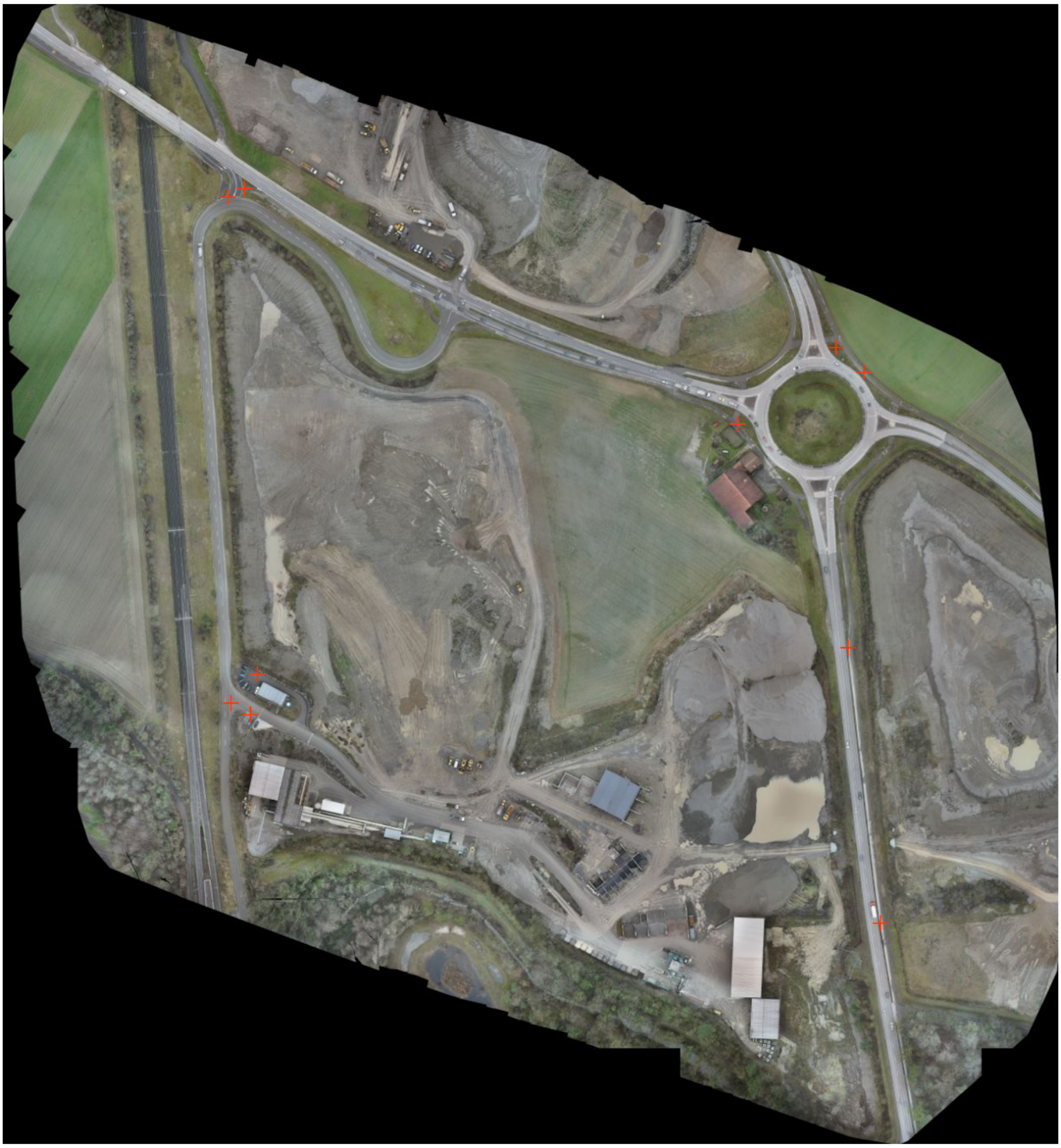

FIGURE 3: Orthomosaic of the second test flight. Orange cross marks display the locations of the 10 verification points.

Assessment of Absolute Error

The measured coordinates of the verification points (reference data) were loaded as "Check Points" to the post-processing software and were used to assess the accuracy of the georeferencing of WingtraOne RX1 PPK aerial imagery. Importantly, none of these verification points were used in the

[3] Using default template "3D maps" without any modifications.

post-processing optimization process, but only as comparison points for the evaluation. The center location of each verification point in the aerial imagery was precisely computed by marking it on each individual aerial image which the verification point appear on (FIGURE 4). The difference between the computed and measured coordinates in X, Y and Z direction quantifies the accuracy of geolocations in the orthomosaic and point clouds generated from aerial imagery which are acquired by WingtraOne PPK systems. The overall accuracy can be best evaluated by averaging the offset over all verification points and calculating a Mean, Sigma and RMS error for each flight.

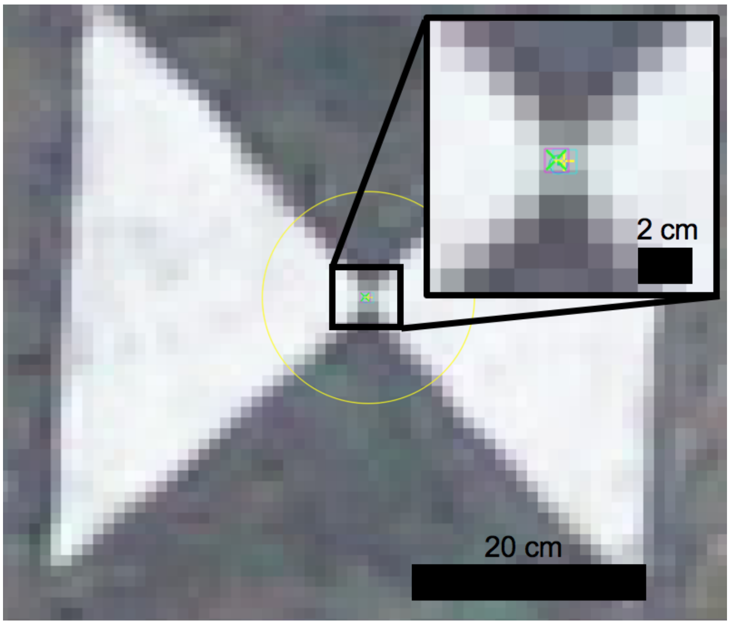

FIGURE 4: Verification point marked in Pix4Dmapper after initial processing step. Inset shows close up to center of the verification point. The yellow '+' displays the marked location of the verification point in this particular image, the green '×' is the reprojection of the estimated 3D point in all images, blue dot inside the blue circle denotes the verification point's location as measured with the reference system.

Assessment of Relative Error

A stockpile volume calculation with the reconstructed point cloud was used to evaluate the relative accuracy of WingtraOne PPK systems. The volume V is measured in Pix4Dmapper by defining the base plane and outline of the volume. Using the $RMS\ Error\ XY$, $RMS\ Error\ Z$, and the number of pixel N_p which constitutes the volume, one can estimate the volume error caused by geolocation inaccuracies $\Delta V_{ppk} = N_p \times (RMS\ Error\ XY)^2 \times RMS\ Error\ Z$. The relative error of volume measurements is therefore $E = \frac{\Delta V}{V}$. Note that this adds to the error provided by Pix4dmapper which is only considering discretization inaccuracies based on the GSD.

Results

Absolute Accuracy of WingtraOne PPK

The accuracy of the point cloud created by aerial imagery from the WingtraOne RX1 PPK is extraordinary high. The point cloud created from images of flight 2 exhibits location errors of the 10 verification points with less than 1 cm in X and Y direction for most of the points and less than 3 cm for 7 of 10 points in Z (TABLE 2). This means that the point cloud has a maximal error of 1 pixel since the GSD of the measurement flight was 0.97cm/px (average). The low mean error of all 10 verification points of 0.01 cm and 0.4 cm in X and Y direction respectively, basically indicates sub-pixel absolute location error of the acquired data, which is highly relevant for general surveying applications. General accuracy can be best estimated and compared by the root mean square (RMS) error of all verification points. Based on flight 2, the horizontal error ($RMS\ Error\ XY$) of WingtraOne RX1 PPK is 1.04 cm. Note that the horizontal error accounts for deviations in both X and Y direction ($RMS\ Error\ XY = \sqrt{(RMS\ Error\ X)^2 + (RMS\ Error\ Y)^2}$). The out of plane error in Z direction is 2.7 cm. Both errors are exceptionally low and demonstrate a new state of the art accuracy of drone based aerial mapping.

Verification Points	Error X [m]	Error Y [m]	Error Z [m]
Verification Point1	0.004	-0.000	0.007
Verification Point2	0.007	0.007	0.013
Verification Point3	0.005	-0.007	0.014
Verification Point4	-0.001	0.016	0.034
Verification Point5	0.011	0.001	0.022
Verification Point6	0.004	0.010	0.051
Verification Point7	-0.005	0.010	0.038
Verification Point8	-0.008	0.006	0.025
Verification Point9	-0.006	0.003	0.016
Verification Point10	-0.009	-0.002	0.017
Mean	0.000171	0.004513	0.023718
Sigma	0.006652	0.006605	0.012864
RMS	0.006654	0.008000	0.026983
RMS XY / Z	**0.010406**		**0.026983**

TABLE 2: Individual location error of each verification point in the orthophoto of Flight 2.

The reliability and repeatability of these good results are demonstrated by the consistent results in all three flights (TABLE 3). Mean, Sigma and RMS error for the same ten verification points are all in the similar range and are maximum 1.1 cm in X and Y and 2.7 cm in Z direction for all three flights. Most noticeably, these high accuracy results were acquired with non optimal light conditions as the high ISO values up to 2500 indicate.

Taking an average over all flights, the horizontal and vertical RMS errors are 1.3 cm and 2.3 cm respectively. These low errors strikingly demonstrate the ultra high accuracy and repeatability of WingtraOne PPK systems.

Flight No.	Error	X [m]	Y [m]	Z [m]
1	Mean	-0.006521	0.004180	0.018184
	Sigma	0.008781	0.006342	0.011808
	RMS	0.010937	0.007596	0.021681
	RMS XY / Z	0.013316		0.021681
2	Mean	0.000171	0.004513	0.023718
	Sigma	0.006652	0.006605	0.012864
	RMS	0.006654	0.008000	0.026983
	RMS XY / Z	0.010406		0.026983
3	Mean	-0.009414	-0.001308	0.016329
	Sigma	0.006055	0.008937	0.010986
	RMS	0.011193	0.009032	0.019680
	RMS XY / Z	0.014383		0.019680
Average of three flights	Mean	-0.005255	0.002462	0.019410
	Sigma	0.007258	0.007387	0.011911
	RMS	0.009818	0.008232	0.022989
	RMS XY / Z	**0.012812**		**0.022989**

TABLE 3: Overview of mean, sigma and RMS location error of all verification points for each flight and average of all flights.

Relative Accuracy of WingtraOne PPK

The relative accuracy within the dataset can be estimated by the sigma error calculated from all verification points. Average sigma error for all three flights is well below 1 cm in X and Y and below 2 cm in Z direction which is an excellent value for reconstructed point clouds.

This good result can be further highlighted by a model calculation for a volume measurement in the reconstructed point cloud. A stockpile volume of a gravel pile is measured using the same base layer marked in all three point clouds. The volume calculated is 72.81 m^3, 72.90 m^3 and 75.79 m^3 in flight 1 to 3 respectively.

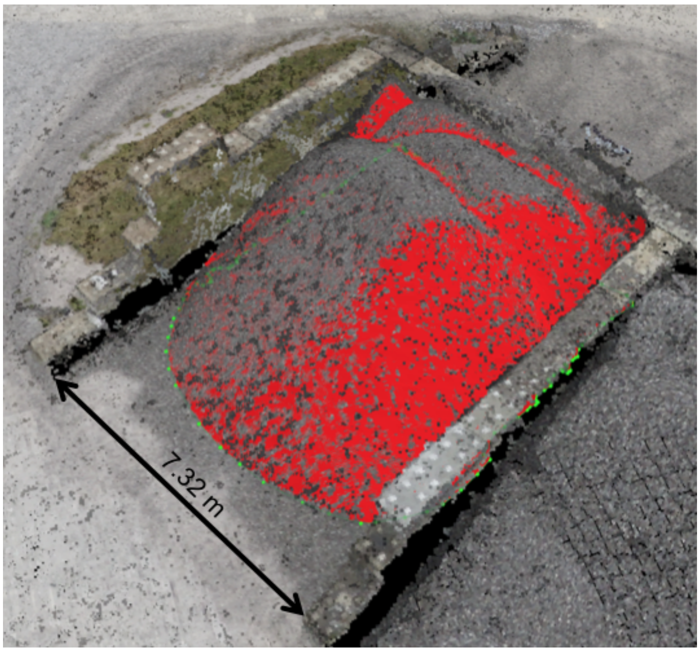

FIGURE 5: Gravel stockpile volume inside vertical walls marked in Pix4Dmapper.

The high accuracy of WingtraOne RX1 PPK systems with an average RMS error of 1.2812 cm in horizontal and 2.2989 cm in vertical direction results in a volume error of $\Delta V_{ppk} = 2.0\, m^3$ or $E_{ppk} = 2.7\,\%$ relative error caused by location errors. Notably this independent error calculation matches the spread of the three separate measurements of the volume on the same geolocation.

Conclusion

WingtraOne PPK system demonstrated remarkable accuracy and highly efficient data acquisition in aerial mapping. In three independent test flights with a WingtraOne RX1 PPK, an average RMS error of 1.3 cm in horizontal and 2.3 cm in vertical direction was achieved without using any GCP in the optimization process. Apart from that, the system is capable of bringing down the relative error of a gravel pile volume measurement to only 2.7%. With the top in class 40 MP Sony RX1 Mark II camera, WingtraOne PPK can acquire aerial imagery with less than 1 cm/px ground sampling distance. This highly exact and high resolution aerial data enables new level of precision in surveying applications with unparalleled data quality.