Case Study

IN-Fusion PP-RTX Crewed Airborne

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POSPac PP-RTX™

www.applanix.com/products/pp-rtx.htm

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Introduction

Introduced in 2011, Trimble's real-time CenterPoint RTX® service provides centimeter-accurate positions for real-time applications. This service depends on generating precise orbit, clock information, and atmospheric delay models in real-time for GNSS satellites (GPS, GALILEO, GLONASS, BEIDOU, QZSS). It operates through Trimble's dedicated worldwide network of tracking stations.

POSPac™ Post-Processed CenterPoint RTX® (**PP-RTX**) is a cloud-based global GNSS correction service that employs Trimble RTX technology to deliver centimeter-level post-processed positioning accuracy **without** the need for base stations. PP-RTX serves as an alternative processing mode to the Single Base, Applanix® SmartBase™, and Multi-Single Base correction methods for GNSS-Inertial Trajectory generation.

The newest ***IN-Fusion PP-RTX***™ feature in POSPac version 9.1 no longer necessitates the uploading of trajectory data to the Cloud Server. RTX Correction data can now be logged either in real-time (APX & AP+ products) or acquired via an internet connection in POSPac minutes after data acquisition. The quality and performance of PP-RTX have significantly improved over the years, surpassing traditional post-processing modes. For detailed information and a comprehensive overview of all benefits, please refer to our PP-RTX website.

Fig 1: UltraCam Eagle

Background

This case study focuses on Crewed Airborne photogrammetric data utilizing the Vexcel UltraCam Eagle v4.1 (see Figure 1) equipped with an AP+60 GNSS-INS system from Trimble Applanix. The primary goal of this exercise is to demonstrate the absolute accuracy in 3D derived from stereo image point measurement by utilizing the ***IN-Fusion PP-RTX*** processing mode in POSPac MMS.

The traditional Single Base (IN-Fusion Single Base) processing mode is used to produce a reference for the analysis presented here. The assumption is that the Single Base mode, leveraging a nearby base station, would traditionally yield the best possible GNSS-INS trajectory solution for direct georeferencing of the photogrammetric images.

Test Area

The test area (fast RTX region) is located in Austria near the city Graz. The data were collected with an image resolution of 5 cm (GSD). It consists of a small block of 40 images flown in 4 north-south strips. Ground control points (GCPs = 10) are spread over the area, referenced in ETRF00 frame at epoch Jan 1, 2000.

Fig 2: Image Block Overview - Orthomosaic

The GCPs are primarily manhole covers. While some GCPs are at the edge of the image block, enabling measurement in only one or two image stereo pairs, others are located in the center supporting multi-image measurements for better redundancy (see Fig 3).

In order to achieve the highest positioning accuracy of the aircraft trajectory, the distance between the aircraft and the dedicated base station was intentionally kept well within 20 km. This is intended to mitigate the GNSS error budget and alleviate datum-related tension in the Exterior Orientation parameter (EO) derived from the GNSS-INS trajectory.

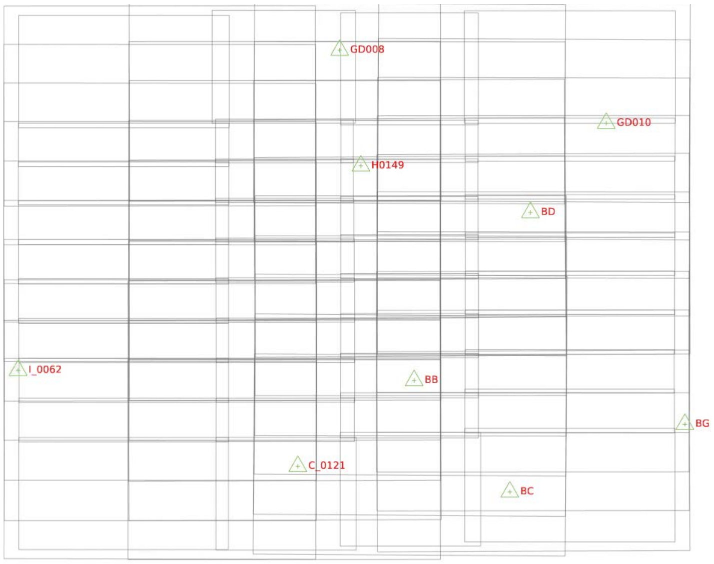

Fig 3: Image Block Overview with GCPs

Data Evaluation

The GNSS-INS trajectory, also referred to as SBET (smoothed best estimate of trajectory), underwent post-processing in both the ***IN-Fusion Single Base*** and ***IN-Fusion PP-RTX*** modes. In both scenarios, we achieved 100% fixed ambiguity epochs. All lever arms, such as GNSS offset and IMU offset, were considered known parameters and kept fixed during post-processing to minimize errors and noise. Prior to the study, the UltraCam Eagle underwent boresight calibration to address any misalignment between the IMU and Camera sensor. The derived boresight angles were applied during the export of the exterior orientation (EO) parameter into the UTM grid referenced in the ETRF2000 frame.

The resulting EO parameters at images exposures from both Single Base and PP-RTX processing were used to generate stereo point measurements at the GCPs from the multi-stereo constellations. The initial focus was on the direct georeferencing (DG) approach, emphasizing that no Aerotriangulation (AT) was conducted before measuring the GCPs in the multi-stereo images. The obtained Root Mean Square (RMS) performance is thus entirely based on direct georeferencing (DG) derived from the GNSS-INS trajectory.

The statistics presented below (refer to Table 1) are derived from 10 Ground Control Points (GCPs) distributed across the terrain. The average coordinate for each GCP was calculated from all stereo measurements taken, and then compared to the original GCP coordinate to determine the Root Mean Square (RMS).

GSD = 5 cm		**RMS *[m]***			**RMS *[Pixel]***		
Mode	Description	X	Y	Z	X	Y	Z
DG Single Base	Direct Georeferencing Single Base	0.04	0.01	0.15	0.8	0.3	2.9
DG PP-RTX	Direct Georeferencing PP-RTX	0.02	0.02	0.13	0.5	0.3	2.7

Table 1: DG Performance with Single Base and PP-RTX Mode

Examining the RMS values of the direct georeferencing (DG) results in both GNSS-INS processing modes reveals no significant difference in three dimensions (3D). The PP-RTX result is slightly superior, achieving a horizontal accuracy of 0.5 pixels and a vertical accuracy of under 3 pixels. This substantiates that PP-RTX is a strong potential processing alternative to using dedicated base stations or SmartBase.

In addition to the above-mentioned pure Direct Georeferencing (DG) approach, Aerial Triangulation (AT) has been used and the results have been analyzed in the remainder of this chapter.

Both relative and absolute Aerotriangulation (AT) were processed to assess any potential improvements as follows:

- The relative Aerotriangulation involves a “free” AT without any GCPs. Relative AT is primarily used to improve the relative orientation between stereoscopic image pairs. This typically results in the elimination of undesirable remaining y-parallax in stereoscopic models.
- Absolute Orientation which is accomplished in this case using the inertial/GNSS photo centers and GCPs.

The results of the relative Aerotriangulation (AT) don’t improve the DG results in absolute sense. As said, the relative AT typically removes y-parallaxes between the stereo images allowing better stereoscopic vectorization.

The use of the AT with a single Ground Control Point (GCP) contributes to the potential removal of datum shifts. For the given project, it leads to a significant improvement in the final absolute accuracy, particularly in the vertical component, while the impact horizontally is minimal. Specifically, the vertical accuracy improves by approximately 2 pixels, decreasing from 3 pixels to below 1 pixel performance.

On the other hand, the vertical accuracy of any ground object, measured in stereoscopic mode, is directly correlated with the Base-to-Height (B/H) ratio - the larger the B/H ratio, the better the ground object vertical accuracy. In most cases, the B/H ratio has more impact on the ground object vertical accuracy than the EO parameter accuracy.

The absolute Aerotriangulation (AT) results with a single Ground Control Point (GCP) is in Table 2 below:

GSD = 5 cm		**RMS *[m]***			**RMS *[Pixel]***		
Mode	Description	X	Y	Z	X	Y	Z
Absolute AT with x1 GCP	Absolute AT with a single GCP and datum shift estimation	0.03	0.01	0.04	0.6	0.3	0.8

Table 2: AT Performance based on PP-RTX EO and 1 GCP

Thanks to the precise GNSS-INS Exterior Orientation (EO) parameters derived from IN-Fusion PP-RTX processing, there is no need to feed numerous GCPs, especially when the Camera's Interior Orientation is well-established and stable. A single GCP suffices to address a potential datum defect and optimize the 3D performance in the image block.

Please note that the comparison between the adjusted GCP coordinates and the original GCP coordinates, resulting from the Aerotriangulation with all GCPs, reveals smaller RMS values (X = 2 cm, Y = 1 cm, Z = 2 cm). This even outperforms the expected performance of 1/3 pixel horizontally and 2/3 pixel vertically. This outcome can also be attributed to the constraints imposed by the a-priori standard deviation applied to the GCPs.

Conclusion

The case study demonstrates that ***IN-Fusion PP-RTX*** revolutionizes the GNSS-INS post-processing in POSPac, replacing the traditional processing modes like Single Base and SmartBase in the crewed airborne mapping industry. Consistent performance is attainable globally through a single button function in POSPac. Numerous significant benefits over traditional processing modes include:

- No base station(s) required
- No baseline restrictions
- Worldwide coverage
- Correction data available from real-time logging or within minutes after mission completion through POSPac
- No frame/datum doubts - PP-RTX utilize latest ITRF frame
- Improves efficiency and productivity
- Single button function
- Subscription license, annually or discounted for multi-years
- 24/7/365 monitored service
- CM level accuracy

The direct georeferencing (DG) results, with less than 1 Pixel horizontally and less than 3 Pixel vertically, mitigate the requirement for an Aerotriangulation (AT) in certain applications such as orthophoto generation and mosaicing. For other projects like stereoscopic vector extraction an AT can be conducted with minimum field efforts, as the process does not require numerous GCPs.

For more information

For more information, contact our Customer Support Team (techsupport@applanix.com) or visit our Customer Support Portal.

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Contact your local Authorized Distribution Partner for more information.

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