Case Study

IN-Fusion+ PP-RTX 2
Mobile Mapping Open Sky

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Overview

Introduced in 2011, the Trimble real-time CenterPoint® RTX correction 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.

Applanix 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 latest iteration of PP-RTX is **IN-Fusion+ PP-RTX 2**, capable of handling multi-frequency and multi-satellite constellations, including the new signals from the Beidou-III generation.

IN-Fusion+ PP-RTX 2 contributes to enhanced robustness, reliability, and reduced convergence time.

Fig 1: Trimble MX50 I Mobile Mapping

Background

This case study focuses on Mobile Mapping data in open sky terrain utilizing the Trimble MX50 product. The MX50 employed in this study is equipped with two LiDAR sensors (left/right), a spherical camera, and an AP20 GNSS-INS system from Trimble Applanix. The objective of this exercise is to showcase the absolute accuracy in the 3D point cloud by utilizing the **IN-Fusion+ PP-RTX 2** processing mode in POSPac MMS.

To establish a reference, the traditional Single Base (IN-Fusion+ Single Base) processing mode is employed. The assumption is that the Single Base mode, leveraging a nearby base station, would yield the best possible GNSS-INS trajectory solution for LiDAR georeferencing (point cloud).

Test Area

The test area (fast RTX region) for the open sky data set is located in Biberach, Germany. The data were collected in an industrial area in 2 runs which were basically loops. Each run/loop is approximately 1.2 km.

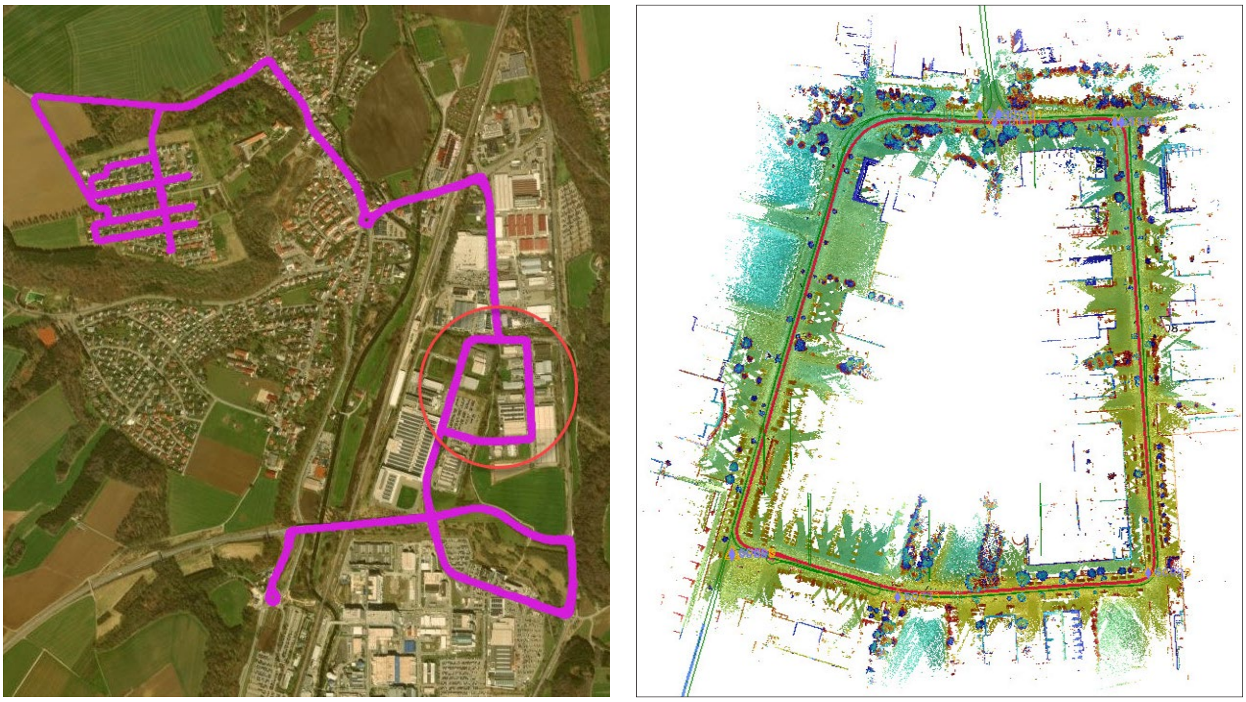

Fig 2: Left - Entire GNSS-INS Trajectory, Right - LiDAR recorded loops

3D and vertical ground control points (GCPs) have been strategically placed. These points underwent surveying through the establishment of a dense reference point network using GNSS technology and Trimble terrestrial 3D Laser. All surveyed points (GCPs) are referenced in the ETRS89 frame. To mitigate potential datum defects, the same base station (same coordinates!) was utilized for GCP surveys and GNSS-INS trajectory post-processing (Single Base mode). Additionally, the baseline length was kept < 5 km. This approach ensures that any datum-related issues are excluded from the error budget.

The vertical GCPs were positioned along the road without any accompanying identification marks.
In contrast, the 3D points are discerned as road paintings or manhole covers within the point cloud.

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 2** modes. In both scenarios, we achieved 95% - 100% fixed ambiguity epochs. All lever arms, such as GNSS offset, IMU offset, and DMI offset, were considered known parameters and kept fixed during post-processing to minimize errors and noise. Prior to the study, the MX50 system underwent boresight calibration to address any misalignment between the IMU and LiDAR sensors.

The resulting SBETs from both Single Base and PP-RTX processing were utilized to generate independent point clouds in Trimble Business Center (TBC). The accuracy evaluation comprised two phases. Phase 1 focused on vertical performance using ground control points (GCPs) on the street, while Phase 2 concentrated on horizontal performance using marked GCPs.

Vertical Performance

The 19 non-marked points are evenly distributed along the 1.2 km loop. The extraction of delta height between the vertical ground control point (GCP) and the point cloud (LAS) was conducted automatically. Given that there are 2 runs/loops, and each run involves both left and right LiDAR sensors, we individually compared each of the 4 resulting point clouds against the 19 vertical GCPs.

The **IN-Fusion+ Single Base** processing mode served as our high-quality reference. From this reference, the following statistics were derived (unit is cm):

Unit [cm]	Left LiDAR		Right LiDAR		Total
Value	Run 1	Run 2	Run 1	Run 2	
Mean	-1.6	-0.9	-2.2	-1.4	-1.5
StdDev	0.7	0.7	0.7	0.6	0.7
RMS	**1.8**	**1.1**	**2.3**	**1.5**	**1.7**

Table 1: Absolute vertical accuracy (cm) based on IN-Fusion+ Single Base Trajectory

The utilization of the **IN-Fusion+ PP-RTX 2** processing mode results in a vertical root mean square (RMS) of 1.8 cm, making it comparable to the statistics obtained from the **IN-Fusion+ Single Base.**

Unit [cm]	Left LiDAR		Right LiDAR		Total
Value	Run 1	Run 2	Run 1	Run 2	
Mean	2.9	0.6	2.3	0.2	1.5
StdDev	1.0	0.8	1.0	0.8	0.9
RMS	**3.0**	**1.0**	**2.5**	**0.8**	**1.8**

Table 2: Absolute vertical accuracy (cm) based on IN-Fusion+ PP-RTX 2 Trajectory

The overall absolute accuracy (RMS) is statistically consistent, reaching down to 1–2 mm. To assess relative accuracy, one can examine the standard deviation (StdDev), which is approximately 1 cm based on the trajectory derived from **IN-Fusion+ PP-RTX 2** processing.

Horizontal Performance

Nine (9) ground control points (GCPs) were employed to assess the absolute horizontal performance. Measuring points in the point cloud is a task that demands some experience; nevertheless, the noise level can be influenced by the operator's skill. In this scenario, the distinction between Left and Right LiDAR was not made. Instead, the runs/loops were treated separately, and the GCP residuals were derived from each individual point cloud. The outcome for the trajectory derived from the Single Base processing is presented below:

Unit [cm]	Run 1	Run 2	Total
StdDev	0.7	0.8	0.8
2D RMS	**2.3**	**2.1**	**2.2**

Table 3: Absolute horizontal accuracy (cm) based on IN-Fusion+ Single Base Trajectory

Same as for the absolute vertical performance, the horizontal performance is statistically almost identical between the Single Base and PP-RTX 2 solution. The horizontal RMS is below 3 cm:

Unit [cm]	Run 1	Run 2	Total
StdDev	0.8	1.0	1.0
2D RMS	**2.6**	**3.1**	**2.8**

Table 4: Absolute horizontal accuracy (cm) based on IN-Fusion+ PP-RTX 2 Trajectory

The 2D relative accuracy is around 1 cm which matches the vertical relative accuracy.

3D Performance

By combining the horizontal and vertical absolute root mean square (RMS) values, we achieve a 3D absolute performance of **2.7 cm** with base station processing and **3.4 cm** with the latest PP-RTX 2 processing mode.

Conclusion

The 3D absolute accuracy achieved with PP-RTX 2 processing, at **3.4 cm**, surpasses our standard specification for PP-RTX processing in favorable GNSS environments. Typically, we anticipate a horizontal root mean square (RMS) of 3 cm and a vertical RMS of 6 cm. The additional trajectory data before entering the LiDAR test area proved beneficial, facilitating a successful convergence.

Although the data were collected in a RTX fast region where the solution should converge within 1–2 minutes, the percentage of fixed epochs (96%) in PP-RTX 2 mode affirms the robust and reliable performance of **IN-Fusion+ PP-RTX 2** in optimal GNSS environments. This study provides evidence that **IN-Fusion+ PP-RTX 2** is an efficient processing mode for georeferencing sensor data in the mobile mapping (land) industry under GNSS open-sky conditions, eliminating the need to process GNSS-INS data with a nearby base station.

LiDAR QC I Open Sky

Applanix LiDAR QC Tools guarantee the highest level of georeferencing accuracy by ensuring the uniformity of point clouds through a robust global Voxel iterative least squares adjustment (LSQ). While the impact of LiDAR QC Tools is not anticipated to be significant under ideal GNSS conditions, the tools were employed for the 2 runs/loops in an open sky scenario to assess their effect.

The vertical difference between the runs was a maximum of **2.5 cm**, falling within the expected range of accuracy. However, LiDAR QC is capable of correcting for this difference, ensuring a 100% match between the runs. The screenshots below illustrate the impact before and after using LiDAR QC Tools.

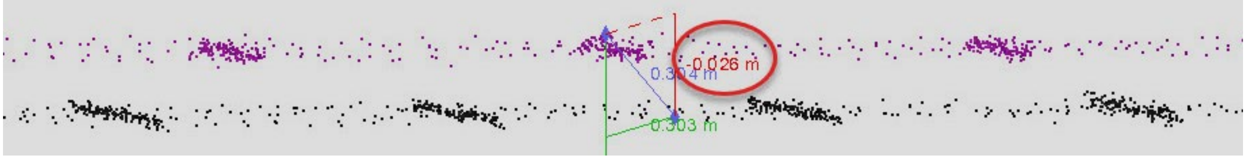

Fig 3: Vertical profile 2 runs before LiDAR QC Tools

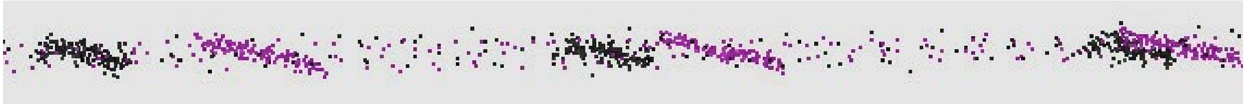

Fig 4: Vertical profile 2 runs after LiDAR QC Tools

The same effect is inherent in 2D by looking from the top at building edges.

Nevertheless, as mentioned earlier, this correction is minimal and is attributed to the favorable GNSS conditions. The true strength of LiDAR QC becomes evident in areas with critical or denied GNSS signals.

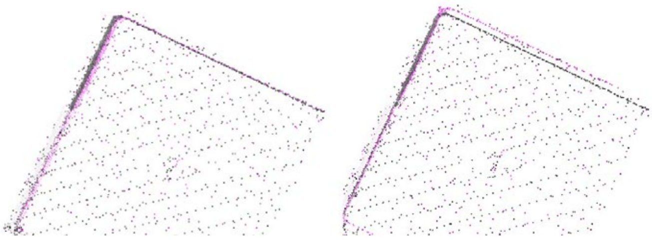

Fig 5: Left - after LiDAR QC, Right - before LiDAR QC

For more information

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

Acknowledgement

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