Optimizing the Accuracy and Efficiency of Mobile Mapping and Surveying using the Latest GNSS Constellations and Frequencies and LiDAR Adjustment Technology

Joseph HUTTON, Nilesh GOPAUL, Jau-Hsiung WANG, Mohamed MOSTAFA, Anna JARVIS, Vi HUYNH, Srdjan SOBOL, Jerry WANG, Terence FU, Xue-Fen ZHANG, James LUTES, Canada, Manfred SEVER, Nico JAEGER, Germany

Key words: Mobile Mapping, Direct Georeferencing, GNSS, Inertial

SUMMARY

Collecting geospatial data from a mobile platform such as an aircraft, land vehicle, marine vessel and even human portable device is a well proven method for highly accurate and cost-effective surveying, mapping, and 3D reality capture. This is especially true when autonomous platforms such as drones and robotic land vehicles are deployed to carry the sensor payloads (i.e. cameras and/or LiDAR sensors). The data from the sensor payloads are georeferenced using a high-rate position and orientation solution computed by combining measurements from GNSS, IMUs, odometers, magnetometers, cameras, and LiDAR. The typical method for this multi-sensor integration is through the use of an Aided-Inertial Kalman Filter based architecture in which the data is post-processed, which offers the advantages of processing the data both in the forward and reverse directions. Recent expansions of the GNSS constellations (including BeiDou III) has resulted in over 100 satellites with multiple frequencies in full operation that can now be used for accurate positioning in what were previously marginal conditions. In addition, the introduction of low-cost, high-performance, miniaturized LiDAR scanners now provide a cost-effective method of measuring relative position and orientation that can be used to correct drifts in the trajectory when GNSS is obstructed. Trimble's Applanix POSPac™ 9 software using Trimble© ProPoint™ GNSS, Trimble CenterPoint© RTX, Applanix IN-Fusion+™, and Applanix PCDA™ technology is an advanced Aided-Inertial post-processing software package that has been optimized for mobile mapping and surveying applications in all environments. This paper presents how POSPac 9 incorporates the latest GNSS constellations and frequencies to produce unparalleled position and orientation accuracy for georeferencing mobile sensor data, and how the Applanix PCDA technology works to use the LiDAR point clouds to optimally correct drifts in the trajectory when GNSS-denied environments. Test results from land vehicle data sets collected in deep urban canyons show how including the latest developments in GNSS signal infrastructure with Single Base station carrier phase differential processing can result in an increase of position accuracy by over 100% percent. In addition, the results show how data from a Velodyne VLP-16 can be used to correct the trajectory drift due to GNSS outages from meters down to the centimeter level. Furthermore, test results from a series of UAV flights processed in POSPac™ 9 using Post-processed Trimble CenterPoint RTX technology highlights how Trimble's advanced PPP service can reliably obtain centimeter-level positioning even on trajectories as short as 10 – 15 minutes.

Optimizing the Accuracy and Efficiency of Mobile Mapping and Surveying using the Latest GNSS Constellations and Frequencies and LiDAR Adjustment Technology

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1. INTRODUCTION

Mobile mapping involves collecting geospatial data from a mobile (moving) platform for the purpose of surveying and producing high accuracy maps and 3D digital twins in a cost effective way. In these applications, sensors such as Light Detection and Ranging (LiDAR), cameras, hyperspectral imagers and other similar devices are mounted on various platforms including aircrafts, Uncrewed Aerial Vehicles (UAV's), marine vessels, land vehicles and robots, and even human portable platforms to continuously collect images and ranging information of the surrounding environment as the vehicle moves. By accurately measuring the position and orientation of the sensors during this movement, each pixel, range, and point can be directly assigned a geographical location, thus enabling a 3D reconstruction of the surroundings (Hutton and Mostafa, 2005).

Figure 1. Trimble UAV (left) and Trimble SPOT Robot with LiDAR Scanner (right)

The position and orientation of the sensors is determined by combining high-rate measurements from technologies such as Global Navigation Satellite Systems (GNSS), inertial measurement unit (IMU), cameras (photogrammetry), odometry (mechanical and optical), magnetometer and LiDAR in an Aided-Inertial sensor fusion architecture.

2. HIGH ACCURACY GNSS POSITIONING FOR MOBILE MAPPING

GNSS positioning is based on the line-of-sight signals from the satellites in space to measure the ranges from known satellite positions to unknown positions on land, at sea, in air and space (Hofmann-Wellenhof et al., 2001). Carrier Phase GNSS processing is a technique which uses phase measurements of the GNSS radio signals to accurately estimate satellite-to-receiver range from which the user position is computed.

It involves determining the total range consisting of the integer number of wavelengths of the carrier signal to each satellite (called the ambiguity) plus any fraction of wavelengths. The fractions are determined by measuring the phase of the signal, while the integer ambiguities are resolved by simultaneously using multiple measurements to multiple satellites and performing a least squares search. The ability to correctly and accurately estimate the ambiguities is influenced by a number of errors, including multipath, receiver clock offset, satellite clock offset, and atmospheric delays (ionospheric and tropospheric) in the propagation of the radio signals.

A technique called Differential GNSS (or RTK) subtracts the phase measurements made at a local GNSS base station located over a known coordinate with the measurements made at the roving GNSS to remove most of the common errors (such as ionospheric delays). For short baseline Single Base RTK positioning, most of the carrier phase measurement biases can be removed by the between-receiver single differencing because of the strong correlations of the errors in nearby geographic locations. In this case, the remaining dominant errors are from multipath and noise, especially in GNSS harsh environments.

Another technique used for mobile GNSS positioning is called Precise Point Positioning (PPP). In this technique, instead of using measurements from a local base station to remove/reduce common errors in the carrier phase measurements, a global network of stationary receivers are used to estimate the errors directly and apply them to the phase measurements. Similarly to RTK, the residual errors are again predominantly multipath and receiver noises.

The ability to obtain the highest accuracy GNSS positioning solution using either method is directly impacted by the capability of processing more satellites and signals and effectively mitigating multipath errors in the GNSS RTK engine. The most recently added constellation is China's BeiDou III, with full operation in 2020. There are now over 100 satellites available to support GNSS positioning. The quality and accuracy of the final position estimates using carrier phase GNSS is thus highly dependent upon two factors (Misra and Enge, 2001):

1. The number of satellites being tracked and their spatial distribution characterized by the satellite geometry strength. Today, there are 7 different GNSS systems, namely: GPS, GLONASS, Galileo, BeiDou, QZSS, IRNSS and SBAS.
2. The magnitude of the residual range errors from carrier phase measurements after constructing differences

2.1 Trimble ProPoint GNSS Technology

Trimble ProPoint GNSS technology is capable of using all available GNSS signals to deliver more accurate carrier phase RTK and PPP positioning solutions. The increased number of GNSS observables and signals used in the engine improve the measurement availability and redundancy to better mitigate the impacts of multipath, signal diffractions and blockages in GNSS challenging environments.

For RTK, a base station tracking the same constellations and frequencies is required. For PPP, Trimble offers its own CenterPoint RTX (**R**eal-**T**ime E**x**tended) correction service (Leandro et al., 2011). Trimble ProPoint was designed with an optimal data signal filtering approach by combining all of the measurements together into a single filter and estimating the carrier integer ambiguities. This approach provides the most flexible use of all available GNSS signals. The ProPoint engine can use any combination of the frequencies and signals being tracked, even down to a single frequency in harsh tracking environments, to generate the optimal solutions. Empowered with the new robust estimation techniques, the ProPoint engine identifies any measurement that does not match a stochastic model and then will either reject or correct the measurement or adjust the stochastic model assigned to the measurement. In dense urban environments, where the GNSS measurements might contain multiple deteriorated data and outliers, Trimble ProPoint is able to provide precise and reliable position estimation.

2.2 Trimble CenterPoint RTX Correction Service

The Trimble Centerpoint RTX network comprises over 120 high-performance Trimble Alloy and NetR9 receivers with geodetic antennas distributed globally, tracking GPS, GLONASS, BeiDou, QZSS and Galileo satellites (Brandl et al., 2014). Raw data from the network are transmitted continuously to multiple operation centers located around the globe. The operation centers contain redundant communication and processing servers ensuring seamless and reliable data processing.

The processing servers continuously monitor the health of the reference stations around the world and automatically reconfigure the network when problems are detected. Network processors then generate the precise orbit, clock, atmospheric corrections and observation biases for any location on the Earth at a rate of 1 Hz. The precise correction data are then delivered to the rover via NTRIP or over L-Band satellite, and are also logged to a server for post-processing applications. Unlike other PPP products, this data is available for post-processing less than 1 hour after data collection (Doucet et al., 2012). The positioning accuracy convergence time to reach centimeter level accuracy depends primarily on the accuracy of the atmospheric corrections and the number of observables. Globally, the convergence time is less than 15 minutes. In RTX fast regions, where the accuracy of the atmospheric corrections are high due the higher density of reference stations, the convergence time is less than 1 minute. Figure 2 shows the RTX Fast regions.

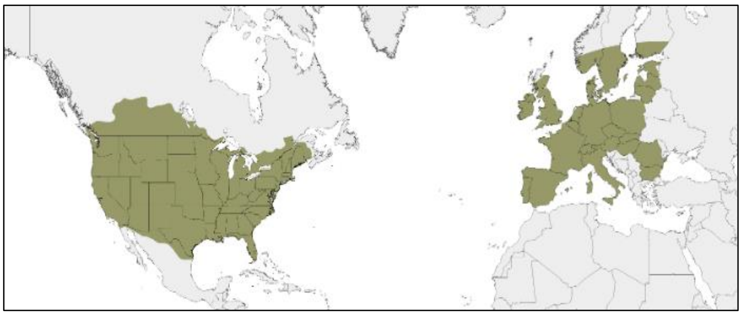

Figure 2. RTX Fast Regions

Since the Trimble ProPoint GNSS engine is capable of utilizing more GNSS observables and signals, the convergence time in non-fast regions can be less than 3 minutes. A low convergence time means centimeter-level positioning solution can be obtained with short trajectories. This is suitable for UAV applications where the missions are usually 10 – 30 minutes long.

2.3 Applanix POSPac 9 GNSS-Aided Inertial Post-Processing for Mobile Mapping

Georeferencing of camera images and LiDAR data collected from mobile platforms is achieved by producing high accuracy, high rate measurements of position and orientation and using them to assign a geographic location to each pixel and point collected. This is normally done in post-mission processing either on a desktop computer or in the Cloud in order to produce the highest accuracy by taking advantage of scalable computational power, internet based correction services, and the ability to process data temporarily in the forward and reverse direction and globally in the spatial domain. The position and orientation measurements are computed by an aided-Inertial algorithm that uses a Kalman Filter based approach to combine measurements from GNSS, IMU, odometry and other types of positioning sensors.

The Trimble Applanix POSPac software is a desktop and Cloud application offered by Trimble that employs an advanced Aided-inertial fusion engine to georeference data collected from any mobile platform. The latest Trimble's Applanix POSPac 9 aided-inertial software has tightly integrated the Trimble ProPoint GNSS engine into its new Trimble Applanix IN-Fusion+ technology to deliver robust and accurate navigation solutions for mobile mapping. Figure 3 illustrates the architecture of Trimble Applanix IN-Fusion+ technology comprising an "aided-inertial" navigation system or Aided INS with aiding sensor components and Trimble ProPoint engine. Figure 3 illustrates the Trimble Applanix IN-Fusion+ architecture.

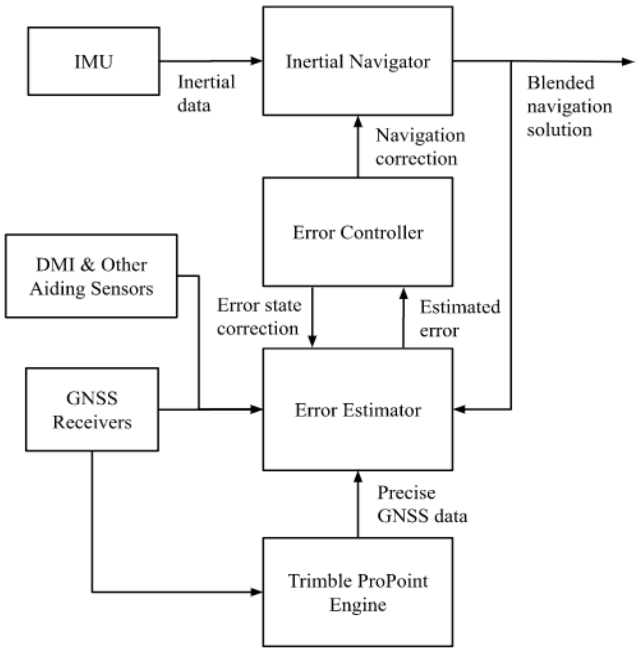

Figure 3. Trimble Applanix IN-Fusion+ Architecture

The Trimble Applanix IN-Fusion+ technology is also an optimal method of “blending” or “fusing” the information of all measurement systems into a robust and accurate position and orientation solution. It automatically adapts the measurement model according to the various quality of input data. With the Trimble ProPoint GNSS technology providing more precise and reliable GNSS RTK and PPP measurements, Applanix IN-Fusion+ technology achieves extremely robust high-rate Aided-INS position output under all types of signal environments.

3. LiDAR BASED POSITIONING FOR MOBILE MAPPING

A mobile LiDAR uses a scanning laser to measure ranges from the vehicle mounted LiDAR ground objects. The ranges are converted into vectors using the GNSS/inertial-measured LiDAR position and orientation (i.e. pose) which are then used to compute 3D point clouds for mapping purposes. However as the vehicle moves, overlapping scans will result in multiple vectors from the LiDAR being measured to the same point in 3D space, therefore enabling triangulation to be used as an independent measurement of the LiDAR’s position and orientation. Such a technique is often referred to as LiDAR Simultaneous Localization and Mapping (SLAM) since it results in both a 3D point cloud and delta pose of the LiDAR sensor. The SLAM algorithm in its simplest form, when starting from vehicle’s initial position and orientation and the map have been initialized, can be summarized by the following:

1. Receive sensor measurements (e.g. LiDAR ranges)
2. Predict vehicle motion (i.e. compute the delta pose)
3. Update vehicle position and orientation based on sensor measurements
4. Update map based on vehicle position and orientation and sensor measurements

These position and orientation measurements are an ideal way of constraining error growth in an Aided-INS architecture when GNSS measurements are not available such as when indoor or in dense urban canyons.

3.1 Applanix LiDAR QC Tools and PCDA Technology

Trimble’s Applanix LiDAR QC Tools are a set of POSPac software tools enabling the highest level of georeferencing accuracy with LiDAR sensors. It simultaneously calibrates boresight and adjusts the vehicle trajectory. The software is hardware-agnostic and can work with any LiDAR system. Ground Control Points (GCP’s) are not needed. The goal is to create a homogenous point cloud and a corrected vehicle trajectory using the LiDAR data.

The LiDAR QC Tools use the Applanix Point Cloud Data Adjustment (PCDA) technology, which is an advanced version of LiDAR SLAM based on a robust global iterative least squares adjustment (LSQ) to solve for the constant IMU boresight angles and adjusts the trajectory. The output of PCDA is then used to generate an accurate point cloud. In this context, the LiDAR becomes an aiding sensor contributing to trajectory optimization.

Applanix PCDA corrects for sensor errors, installation parameter errors, and errors introduced during data collection. It is also used to correct critical trajectory segments when driving in GNSS-denied environments in urban centers and high foliage areas. Creating sufficient point cloud overlap is required in such regions in order to allow Applanix PCDA to calibrate the boresight and adjust the trajectory. Furthermore, the LiDAR-adjusted trajectory can be used to georeference sensor data from other cameras or LiDARs that are mounted on the same platform. Figure 4 illustrates the PCDA process.

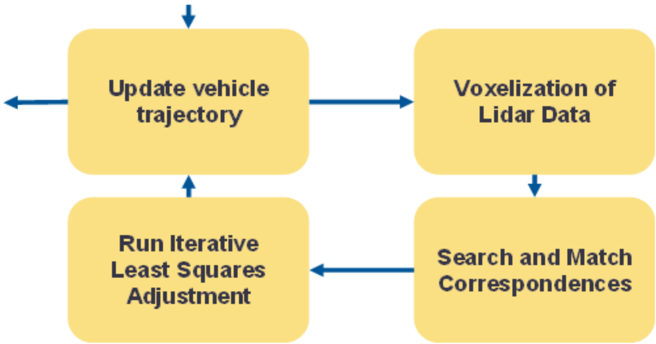

Figure 4. PCDA Process Diagram

4. TEST RESULTS

This section presents and compares results between Trimble's Applanix POSPac 8.9 IN-Fusion and POSPac 9 powered by the new IN-Fusion+ technology which integrates the Trimble ProPoint engine into its workflow. Section 4.1 shows Single Base results for land vehicles in an urban environment, while Section 4.2 presents the **P**ost-**P**rocessed Centerpoint **RTX** (PP-RTX) results for UAV applications. Finally, Applanix LiDAR QC Tools and PCDA processing for land vehicles in an urban environment is presented in Section 4.3.

4.1 Land Vehicle Application using Single Base Station Processing

The POSPac 8.9 and POSPac 9 Single Base RTK positioning solutions were assessed against the reference trajectories for 38 downtown Toronto datasets (equivalent to 72 hours of data). The test trajectories involve multiple loops through the core downtown Toronto areas as shown in Figure 6(left). With numerous skyscrapers and buildings of various heights, from low-rise or multi-story to high rise, the downtown Toronto area provides an extremely challenging environment for GNSS-derived information due to variable conditions of GNSS signal reception. Based on these conditions, this test area serves as an ideal environment for evaluating the aided inertial positioning performance for urban mapping and autonomous navigation applications. A base station located within 10 km from the test trajectories was used to collect the base GNSS data for short-baseline RTK processing. The reference trajectories were generated using the post-processed GNSS RTK-aided inertial positioning solution with the use of a highly accurate navigation grade Ring Laser Gyro based IMU. Through the use of this high-grade IMU, this reference system is able to produce position within 10 cm accuracy even without GNSS.

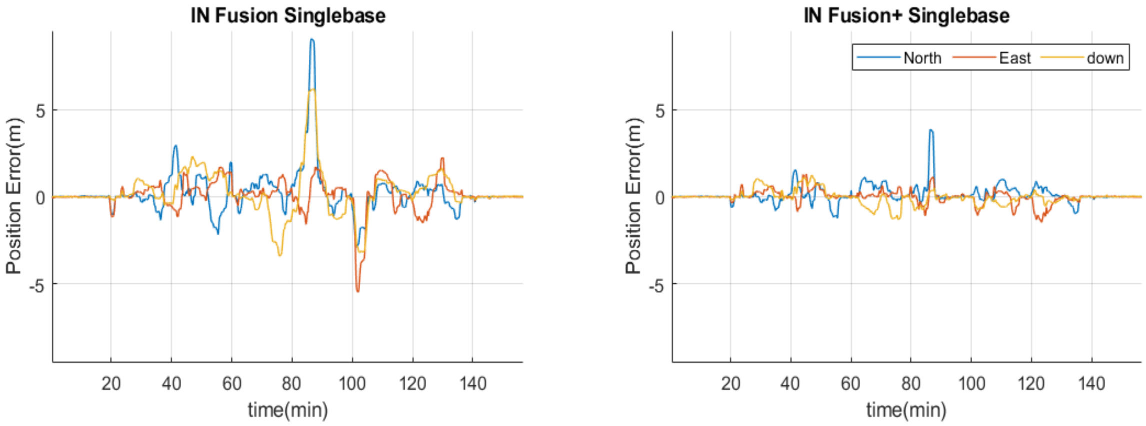

Figure 5: SBET Position Errors for One Dataset

Figure 5 shows the POSPac SBET position errors when processing a downtown dataset collected by Trimble's Applanix LVX product with onboard MEMS IMU using POSPac 8.9 and POSPac 9, respectively. It can be seen that the POSPac 9 solution using the IN-Fusion+ technology has significantly reduced position error drifts and continuously maintained the SBET position accuracy throughout the GNSS challenging environments, whereas the previous generation POSPac 8.9 IN-Fusion Single Base solution suffers larger position error drifts in core downtown Toronto areas.

Figure 6(center) and Figure 6(right) show the altitude-vs-longitude SBET trajectories generated from POSPac 8.9 IN-Fusion and POSPac 9 IN-Fusion+ respectively. These figures show that the IN-Fusion+ solution has much better trajectory overlap compared to the IN-Fusion solution for the multiple loops around the same area. With three loops of the core area repeated this improved overlap in the altitude-vs-longitude trajectories indicates a more accurate SBET solution. Figure 7 shows the number of satellite used in the previous generation engine (left) and Trimble ProPoint engine (right) for the downtown Toronto dataset.

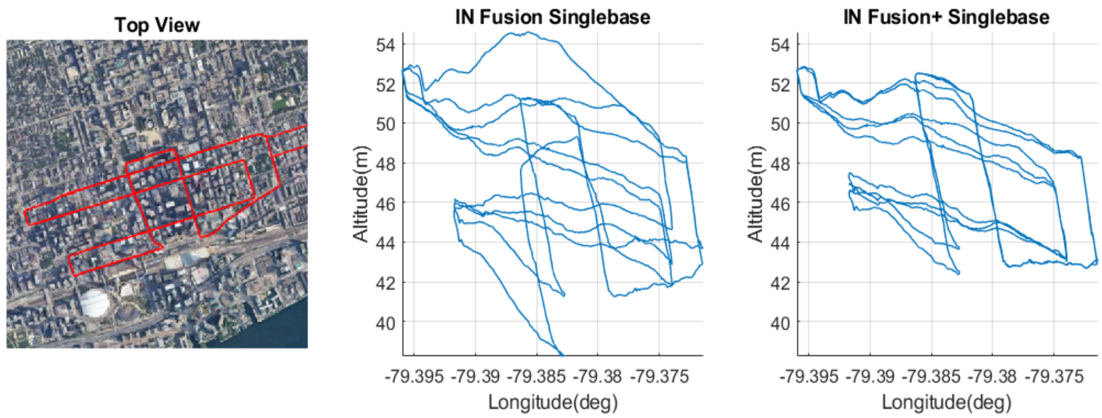

Figure 6. Downtown Toronto Dense Urban (left), IN-Fusion altitude vs. longitude SBET Trajectory (center), IN-Fusion+ altitude vs. longitude SBET Trajectory (right)

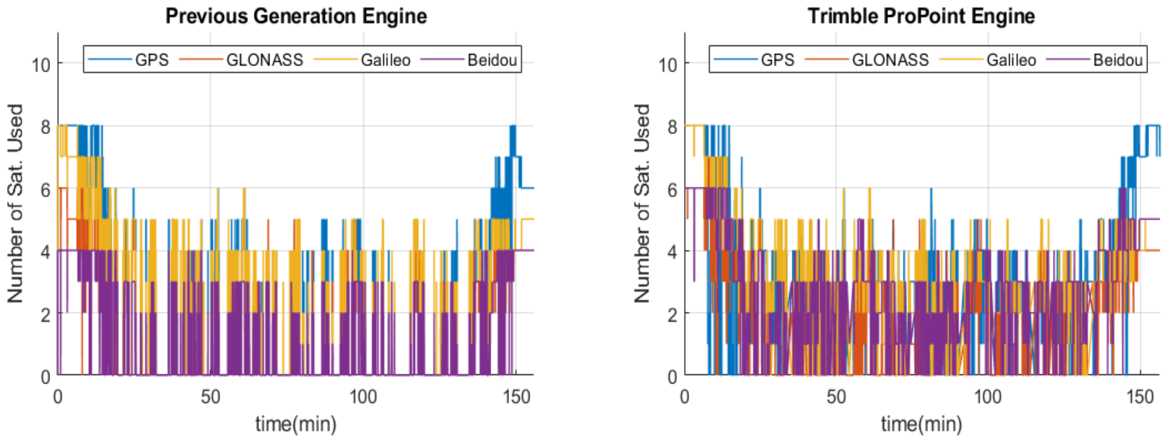

Figure 7. Number of Satellites Used for One Dataset

It can be seen that the Trimble ProPoint has used and processed more satellite observables than the previous generation engine to provide better GNSS measurement redundancy and robustness in GNSS-difficult areas.

Table 1 compares the Applanix IN-Fusion Single Base with Applanix IN-Fusion+ Single Base SBET position solution accuracy for all 38 downtown Toronto datasets for Trimble Applanix LVX system and Trimble AP+ 30 system, respectively. Both products use a cost-effective MEMS IMU with next generation survey-grade GNSS receivers. The product specifications of Trimble Applanix LVX and AP+ 30 are available at (Trimble Applanix, 2018) and (Trimble Applanix, 2022b). Comparing the results in Table 1, the one sigma 3D SBET position error has been reduced from 64.0 cm to 31.9 cm, which is equivalent to 100.89% improvement, for the Trimble Applanix LVX product.

The second system evaluated in this test, the Trimble AP+30, also shows significant improvements with the one sigma 3D SBET position error showing a reduction from 43.2 cm to 20.0 cm, equivalent to 116.22%, improvement. The net result is the more accurate and robust spatial knowledge solution from a cost effective approach, enabling the highest level of productivity in urban HD mapping and autonomous navigation, through the use of the Trimble Applanix POSPac 9 software powered by Applanix IN-Fusion+ technology. Detailed IN-Fusion+ Single Base results can be found in Wang et al, 2023.

Table 1. SBET Position Accuracy and Improvement

System	SBET 3D Position Error (1σ)		SBET Position Accuracy Improvement
	IN-Fusion Single Base	IN-Fusion+ Single Base	
LVX	0.640 m	0.319 m	100.9%
AP+ 30	0.432 m	0.200 m	116.2%

4.2 UAV Application using Trimble Post-processed Centerpoint RTX

This section presents and compares the performance of Applanix POSPac 8.9 IN-Fusion PP-RTX and POSPac 9 IN-Fusion+ PP-RTX using UAV datasets. A UAV dataset is characterized by a short data length (10 to 15 minutes), low altitude with respect to the ground (less than 400m), and high dynamics. Figure 8 shows the top view and the altitude profile for a typical UAV flight. A total of 66 datasets (equivalent to 25 hours of data) were processed and analyzed. The datasets were collected in the RTX non-fast regions and contained BeiDou III signals. The corresponding IN-Fusion Single-Base solutions were used as the reference trajectories in the analysis. The baseline length between the rover and base was less than 2 km to ensure that the estimated positional accuracy was 1 cm RMS in the horizontal and 2 cm RMS in the vertical throughout most of the trajectories. The base station coordinates were in the same coordinate system as the RTX system, namely ITRF2014.

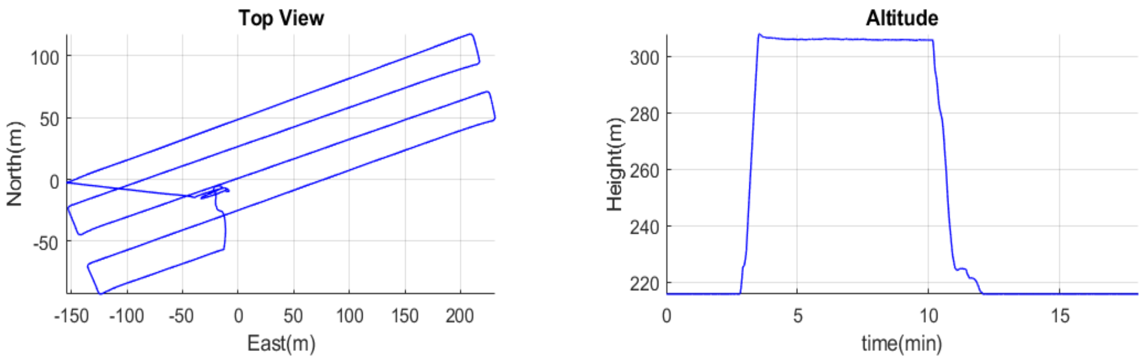

Figure 8. Top view (left) and Altitude (right)

Figure 9 (left) compares the horizontal and vertical position solution of IN-Fusion and IN-Fusion+ PP-RTX for one dataset. The forward plots show that IN-Fusion and IN-Fusion+ take 8 minutes and 2 minutes respectively to converge to centimeter-level positioning accuracy. In post-processing the forward solution is smoothed to provide centimeter level convergence-free positioning accuracy for the entire trajectory, as illustrated in Figure 9 (right).

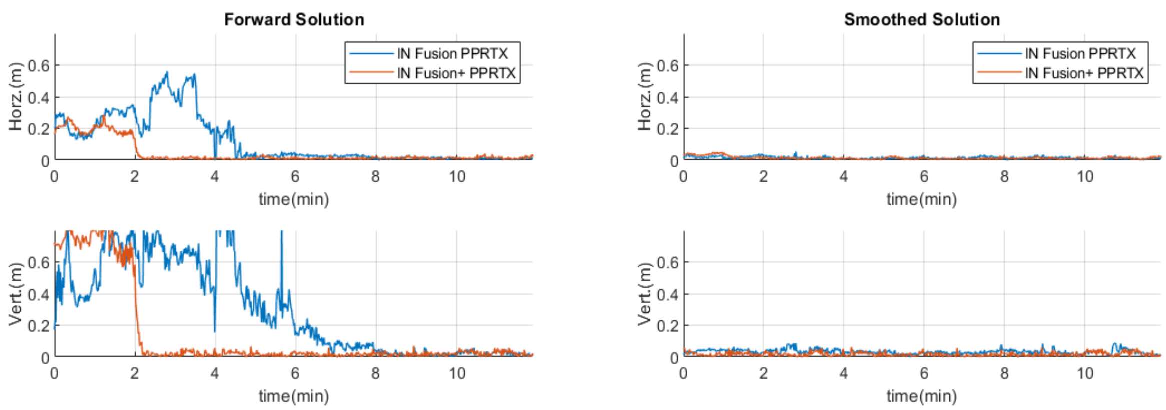

Figure 9. The forward (left) and smoothed (right) solution for One dataset.

Figure 10 shows the number of satellites used in the previous generation engine (left) and Trimble ProPoint engine (right). It can be seen that only the latter used Beidou satellites. This is because the previous engine does not process Beidou III satellites while the Trimble ProPoint engine does. Table 2 compares the statistics of the smoothed position differences for IN-Fusion PPRTX and IN-Fusion+ PPRTX for all the 66 UAV datasets. Compared to IN-Fusion PPRTX, the RMS of the differences in all three components for IN-Fusion+ PP-RTX has improved. That is, the North, East and Down RMS have improved from [4.4, 2.3, 9.4] cm to [1.2, 0.9, 5.5] cm respectively. Such close agreement of IN-Fusion+ PP-RTX and IN-Fusion Single-Base for datasets with short data length is sufficient to meet the requirements for the majority of UAV mapping applications.

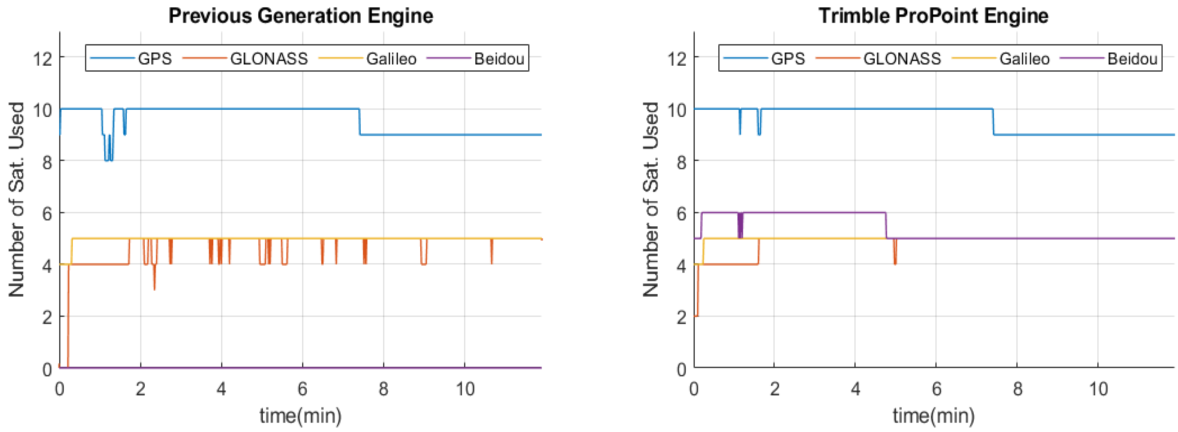

Figure 10. Number of Satellites Used for One Dataset

Table 2. Position difference Statistics PP-RTX vs. IN-Fusion Single-Base

	IN-Fusion PP-RTX			IN-Fusion+ PP-RTX		
Component	mean	1σ	rms	mean	1σ	rms
North(m)	-0.012	0.042	0.044	-0.003	0.011	0.012
East(m)	-0.001	0.023	0.023	0.002	0.009	0.009
Down(m)	0.030	0.089	0.094	0.028	0.047	0.055

4.3 Land Vehicle Application using LiDAR Trajectory Adjustment

For this evaluation, several land vehicle data sets from a Trimble AP+20 and Velodyne VLP-16 LiDAR were collected in downtown Toronto (Figure 11 (left)). The product specifications of AP+ 20 are available at (Trimble Applanix, 2022a). A rectangular loop of 2 km in a deep urban canyon with challenging GNSS coverage was driven three times to generate overlapping LiDAR point clouds. The LiDAR data was processed in LiDAR QC Tools to correct and constrain the drift in the trajectory generated by the AP+20 caused by the degraded GNSS signal reception. Running the LiDAR QC Tools with the Applanix Point Cloud Data Adjustment (PCDA) technology acts to correct the GNSS-Inertial trajectory by using the LiDAR data as an aiding sensor.

This adjustment process can work selectively and hence the full dataset was split into samples and the most critical street that is approximately 500 m long (being on the left side of the loop with the highest skyscrapers in Figure 11) was used for this study. The satellite visibility for this time window was poor which resulted in a degraded position accuracy for the GNSS-Inertial trajectory as reflected by the estimated RMS (see Figure 11(center), Figure 11(right)). The number of satellites in view during the time interval 50 and 90 minutes was no greater than 6 satellites for the individual GNSS systems. As a result of low satellite visibility, the position error estimation (RMS) of the GNSS-Inertial trajectory deteriorates from centimeter-level to decimeter or even meter-level in 3D. In this very challenging GNSS environment the expectation is that the point cloud derived from the pure GNSS-Inertial trajectory won't match between the repeated loops.

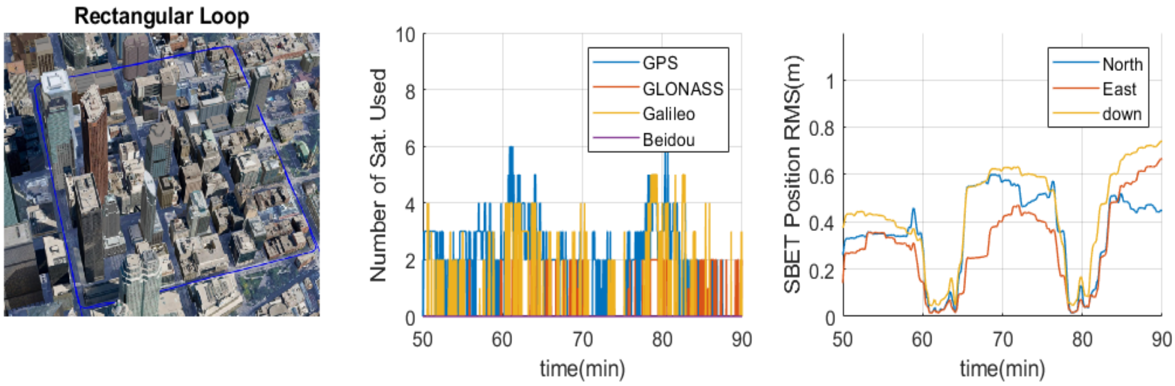

Figure 11: Rectangular Loop Toronto Downtown (left),
Satellite Visibility (center) and Position RMS (right)

When looking at Figure 12 (left) our expectation is confirmed. The green and magenta point colorization present the point cloud from two different loops (repeated scene). Since the boresight calibration was performed prior to this test, this mismatch is purely drift due to poor GNSS reception for a significant amount of time.

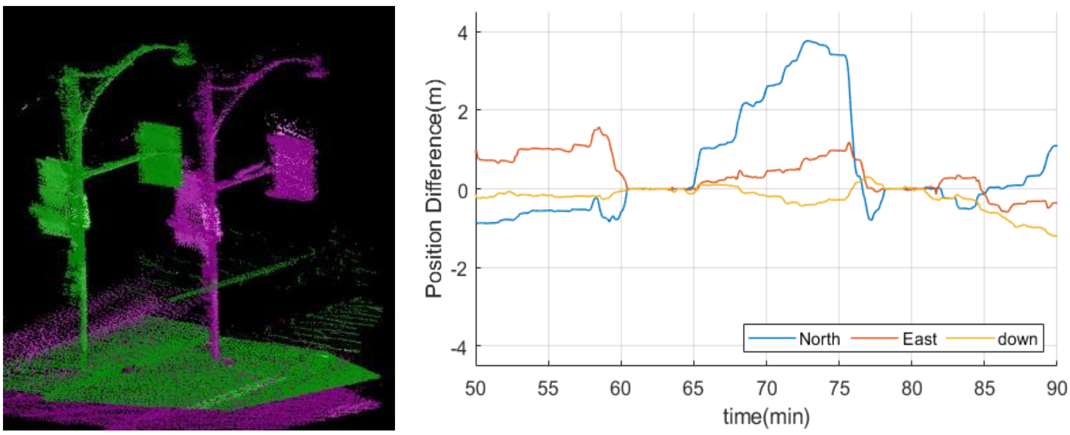

Figure 12: Repeated Scene (left) and
Position difference LiDAR Adjusted Trajectory vs. Original Trajectory (right)

The PCDA technology in LiDAR QC Tools uses the overlapping point cloud to correct the GNSS-Inertial trajectory which is used to georeference the LiDAR data. As previously described, the LiDAR becomes an aiding sensor to optimize the trajectory and remove or constrain the drift. Figure 12 (right) shows the magnitude of the corrected trajectory compared to the original GNSS-Inertial trajectory.

The new point cloud derived from the corrected trajectory produces a much more consistent point cloud between the different loops of the same street. Figure 13 and Figure 14 show some examples of before and after trajectory adjustment where each colour represents an individual loop in the downtown area.

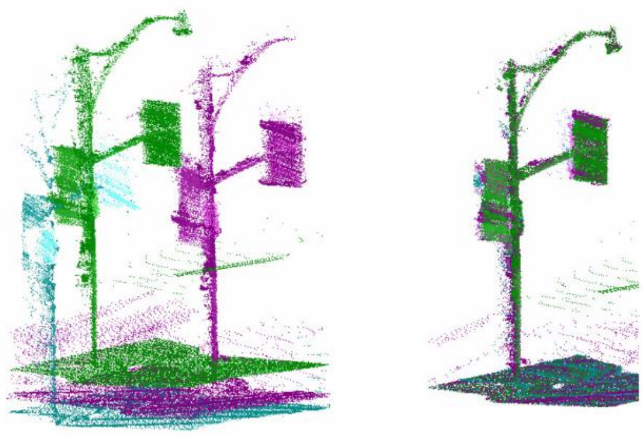

Figure 13: A lamp post before(left) and after(right) LiDAR QC

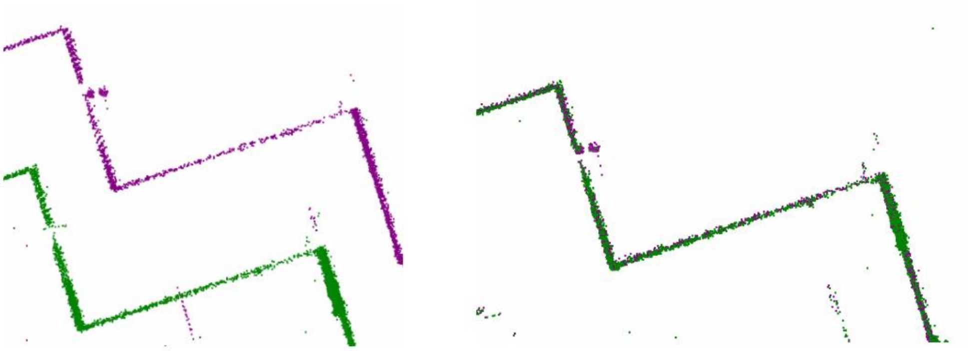

Figure 14: Building Corner before (left) and after (right) LiDAR QC

The LiDAR QC Tools with the Applanix PCDA technology “fuses” all measurements to produce matching point clouds. As we can see from the above example, identical 3D scenes suffering from difficult GNSS tracking in urban environments, where features from overlapping loops differ from decimeters to even meters, can be corrected by using LiDAR QC tools. This improved the repeatability and accuracy of the SBET trajectory as well as the corrected 3D point cloud that maps the real world.

5. CONCLUSION

This paper presented two new features in the upcoming Trimble Applanix POSPac 9 software, namely the Applanix IN-Fusion+, and Applanix PCDA technologies. The Applanix IN-Fusion+ technology integrates the Trimble ProPoint engine that fully supports all modernized satellites and new signals to deliver a robust and accurate navigation solution. Trimble ProPoint can also effectively mitigate multipath errors and outliers in GNSS challenging environments. Applanix IN-Fusion+ can also process Trimble CenterPoint RTX corrections to provide a fast convergent PPP solution ideal for short UAV trajectories. The Applanix PCDA technology used by the LiDAR QC Tools module is an advanced version of LiDAR SLAM based on a robust global Voxel iterative least squares adjustment which optimally corrects drifts in the trajectory when GNSS is obstructed.

Test results from land vehicle datasets collected in urban Toronto showed that with POSPac 9, Single Base station carrier phase differential processing increased the position accuracy by 100.89% for Trimble Applanix LVX products and 116.22% for Trimble AP+ 30 products. Data from a Velodyne VLP-16 LiDAR was used to correct the trajectory drift of an entry-level system through GNSS outages, with accuracy improvements from decimeter or meter accuracy down to centimeter level performance.

Furthermore, test results using IN-Fusion+ post-processed Centerpoint RTX on a series of UAV flights showed that it took less than 3 minutes to converge to centimeter level positioning accuracy in non-fast regions. Therefore, reliable convergence-free cm-level positioning accuracies was obtained even on trajectories as short as 10 – 15 minutes.

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