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Accuracy Report:

Elios 3 with GeoSLAM Connect

GeoSLAM

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Elios 3 with GeoSLAM Connect

This report aims to assess the local accuracy and precision of the LiDAR data captured by the Elios 3 and processed by GeoSLAM Connect. A further report will focus on global accuracy. To evaluate the accuracy of the system, local Plane-to-Plane analysis was undertaken. To achieve this, the Elios 3 data was compared to a reference model created using a Terrestrial Laser Scanner. The precision of the system was also tested through Range Noise analysis.

The results suggest that the Elios 3 with GeoSLAM Connect compares well against a traditional TLS and with the ZEB Revo and ZEB Horizon, which are leading mobile mapping systems in the market.

What is required from a Mobile Mapping System?

The top three requirements for a mobile mapping project:

- Point cloud accuracy and high-quality imagery.
- Scanning speed and time spent on site.
- An integrated seamless software workflow from scanning to deliverables.

This report is going to investigate the first requirement for a successful mobile mapping project, accuracy, and precision. The Elios 3 covers the second requirement by implementing rapid data acquisition in challenging and inaccessible environments, significantly reducing the time spent on- site in comparison to traditional methods. Ensuring the third requirement for a successful mobile mapping project is fulfilled, **GeoSLAM Connect** offers an integrated and automated workflow from data collection to deliverable output.

Introduction

Since 2012, GeoSLAM has been an innovator and a leader in the Simultaneous Localisation and Mapping (SLAM) market. Having developed the first commercial handheld SLAM mobile mapping system in 2012, GeoSLAM has extended skills and experience in the industry, improving SLAM robustness and developing customer-driven solutions for traditionally challenging SLAM environments.

With an evolving and expanding SLAM market, GeoSLAM have joined in a new and exciting partnership with a leading drone inspection company, Flyability. Based in Switzerland, Flyability develops solutions for the inspection and exploration of indoor, inaccessible, and confined spaces. By allowing drones to be used safely inside buildings, Flyability's solutions enable industrial companies and inspection professionals to reduce downtime, inspection costs, and risks to workers. With a global presence in sectors including Power Generation, Oil & Gas, Chemicals, Maritime, Infrastructure & Utilities, and Public Safety, Flyability has pioneered and continues to lead the innovation in the commercial indoor drone space.

Combining mobile mapping with an indoor drone allows for previously inaccessible environments to be mapped to survey standards whilst driving efficiencies for the customer by improving the assessment quality and lowering costs.

Both companies identified the value that a survey-grade SLAM mapping solution would add to Flyability's new and vastly improved drone, the Elios 3, hence the partnership was formed. The partnership aims to combine the drone-based inspection solutions from Flyability with the market- leading SLAM algorithm and software that GeoSLAM delivers.

To show the performance that the new Elios 3 Survey package can provide, this document aims to look at the accuracy and precision of the Elios 3 when **GeoSLAM Connect** is incorporated.

Background

LiDAR is an established active optical remote sensing technique. It has proven to be a powerful surveying tool across a wide variety of sectors for over 40 years. It has been used on spacecraft, airborne, marine, and terrestrial-based platforms.

Traditional ground-based LiDAR systems are tripod-based that can produce millions of data points with sub-mm to mm accuracy and are often used for localised terrain-mapping applications that require frequent surveys. Modern navigation and positioning systems enable the use of water and land-based mobile platforms to create survey-grade mapping data. Data collected from these platforms are highly accurate and are used extensively to map discrete areas, including railways, roads, utility corridors, harbours, and shorelines. GNSS reliant Mobile Laser Scanning systems have the benefit over Terrestrial Laser Scanning (TLS) systems of being able to acquire large complex areas more quickly and efficiently. However, their reliance on high-quality, positional GNSS data makes them poorly suited for indoor, underground, or GNSS-deprived environments.

In these environments, Mobile Mapping systems, with SLAM algorithms, have successfully been used to collect survey-grade data that can be used for rapid floorplan creation in infrastructure mapping, underground monitoring and inspection, time-lapse construction progress management, volumetric stockpile management, and many more.

SLAM

GNSS Mobile Laser Scanning systems typically consist of various sensors including a high-grade inertial measurement unit (IMU), global navigation satellite systems (GNSS), and laser scanners. The laser scanner typically uses a rotating mirror on a 2D plane. To measure in 3D, the scanner must either rotate or move along a trajectory. The scanner orientation and position along the trajectory is determined from the combination of the output from the inertial measurement unit and the global navigation satellite systems. By fusing the laser data (in the form of an angle and range from the scanner) with the independently derived trajectory, a 3D map is created.

SLAM-based Mobile Mapping systems, again, use a 2D scanner that rotates and moves along a trajectory. The 3D map is created only using the laser measurements it acquires and an IMU. No external input from a global navigation satellite system is required. At a single point in time, the system records a 3D map of its immediate environment. As the sensor moves, an algorithm is used to merge the successive overlapping maps, utilising the presence of distinct features such as edges in the environment to establish correspondences between each map. While the sensor is moving and acquiring these maps, the algorithms use sensor measurements to map the environment and locate the sensor within that map. This process for analysing the range data to build a map and determine localisation is known as Simultaneous Localisation and Mapping or SLAM.

There are many factors that must be considered that can affect the overall quality of the resultant 3D map.

Conditions that can potentially affect data quality in real-world measurements include:

- The environment: are there strong features to establish correspondence?
- Atmospheric effects: is there a lot of dust/rain?
- Surface materials and textures: wet surfaces are poor energy reflectors.

In the case of laser:

- Laser beam divergence: divergence forms a larger spot at greater distances.
- The resolution and precision of the instrument may be very good but there is a vast amount of data, hundreds of thousands of points, which are low-pass filtered to mitigate the noise.

From even this limited list of factors, it is possible to see that the accuracy specification of the instrument is only a starting point in understanding the accuracy of the measurement process.

Terminology

When gauging system quality, manufacturers will specify a number of data metrics. The most widely used are accuracy and precision. Measurement accuracy is most universally defined as the degree of conformity of a measured quantity to its actual (benchmark) value, and precision as the degree to which further measurements show the same result. Figure 1shows a diagram of a target to visualise the difference between accuracy and precision. When assessing accuracy, a second measurement system must be used to provide the benchmark value and this system must be of greater accuracy than the system under test. When assessing a Mobile Mapping solution, the industry standard is to utilise either a Total Station (TPS) or a Terrestrial Laser Scanner (TLS).

Other terms which are often discussed are local and global accuracy. However, these terms are more ambiguous in their definition. With respect to Mobile Mapping systems, local accuracy relates to the distance between 2 points in the cloud, where the object can be viewed from a single position, e.g., the dimensions of a single room. Global accuracy relates to the distance between 2 points in the cloud, where the object cannot be viewed from a single position, e.g. the distance between 2 rooms. This report will analyse the local accuracy and precision and a further report will focus on the global accuracy of the system.

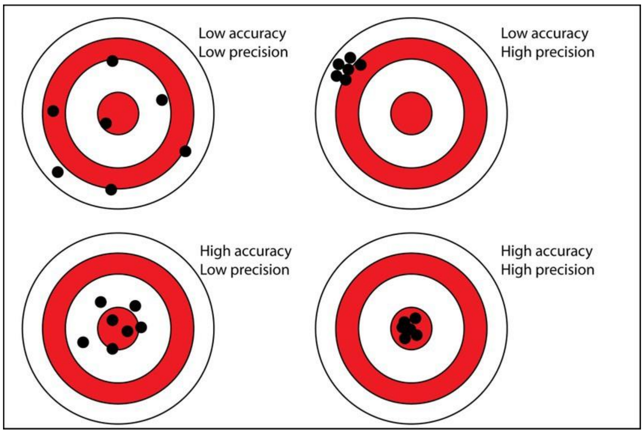

Figure 1. Precision vs Accuracy. Accurate measurements fall in the bullseye. Precise measurements are tightly clustered.

Accuracy Assessments

To evaluate the local accuracy of the Elios 3 with **GeoSLAM Connect** (Survey Package), Plane- to-Plane analysis was carried out. In addition to local accuracy, a Range Noise evaluation was undertaken to assess the precision of the system.

Comparing TLS to Elios 3

To assess the local accuracy of the Elios 3, data was captured from an indoor planar surface environment using the Elios 3 and an industry-standard Terrestrial Laser Scanner (TLS). The TLS was chosen as control as its accuracy exceeds that of a Mobile Mapping solution. The TLS data was used to produce a surveyed reference model that contained a series of known planar surfaces.

Data from a TLS is captured from a singular stationary position and multiple positions are registered together using point matching algorithms. In comparison, a Mobile Mapping system, such as the Elios 3, continuously captures data at multiple positions as the system moves through the environment.

TLS accuracies refer to the accuracy of the system from a single position at a set confidence level. For the TLS system used, a Riegl VZ-400, the manufacturer states accuracy of 5mm at 1-sigma, meaning 68% of all measurements have to be within a range of 5mm. From the Riegl point cloud, the reference model was created to act as the known ground control.

Aligning the Elios 3 point cloud to the reference model

An alignment is required to effectively compare the Elios 3 point cloud to the reference model. An alignment will change the position and orientation of the point cloud data and bring it into the coordinate system of the reference model. To align the whole Elios 3 point cloud to the reference model PolyWorks|Inspector MRS2019 IR3 software was used. PolyWorks is a 3D analysis and quality control software solution used to assess product accuracy. In PolyWorks a manual alignment is used to provide an initial rough alignment of the comparison point cloud (Elios 3) to the reference model. Once complete, the Best-Fit Automatic Alignment function is used to provide a computed transformation matrix between the point cloud and the reference model. The Best-Fit operation is a surface-based alignment tool that iteratively transforms the position and orientation of the comparison point cloud data to minimise the deviation of the point cloud, with respect to the reference model. The rigid transformation matrix calculated is then applied to the point cloud to align the comparison Elios 3 data to the reference model.

Assessing Local Accuracy

The Plane-to-Plane comparison was carried out by fitting planes, to both Elios 3 data and the surveyed reference model and evaluating the Normal Distance between the planes. The Normal Distance is calculated by finding the difference between the extracted plane in the Elios 3 point cloud and the corresponding plane in the reference model. The Normal Distance calculations were carried out using an automated workflow in PolyWorks MRS2019 IR3. This assessment indicates the local accuracy of the point cloud and any variations across the point cloud were identified.

Assessing System Precision

To assess the precision of the Elios 3, Range Noise Analysis was undertaken. Range Noise is the difference between each range reading (point) and the mean range value within the selected area. The areas chosen to assess the Range Noise were the planar surfaces extracted for the Plane-to- Plane comparison. The Range Noise is presented as a Standard Deviation from the mean point of the plane. Hence, Standard Deviation will be the measure of the system precision and is given to
1-sigma. The Standard Deviation was computed using PolyWorks MRS2019 IR3.

Test Environment

To evaluate the accuracy and precision of the Elios 3 with **GeoSLAM Connect**, the data was captured in a standard office environment with 6 planar surfaces, approximately 1m square, located at frequent intervals around the scan. The locations for the planar surfaces can be seen below in Figure 2 and Figure 3.

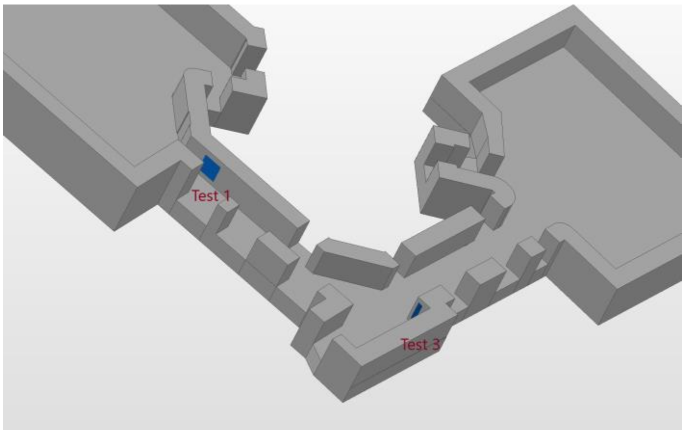

Figure 2. Location of planar test surfaces 1and 3.

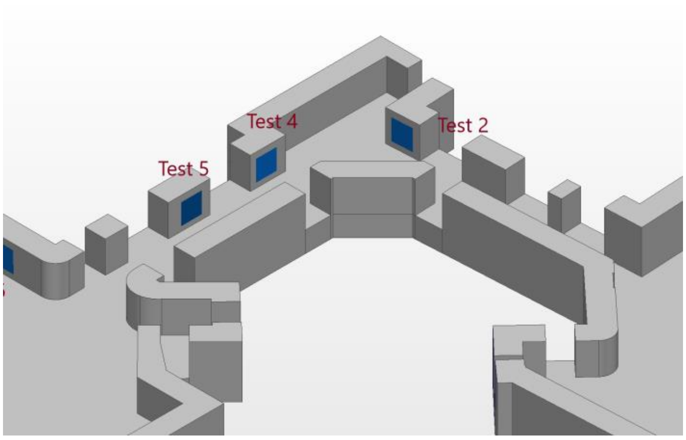

Figure 3. Location of planar test surfaces 2, 4, 5, and 6.

Laser scanning reference spheres (145mm diameter) were placed around the environment to register the Terrestrial Laser Scans to create the reference model. The TLS used was the Riegl VZ-400, and the registration process was undertaken using RiScan Pro V2.14.1. A reference model (Figure 4) was created using the LAZ output from RiSCAN Pro.

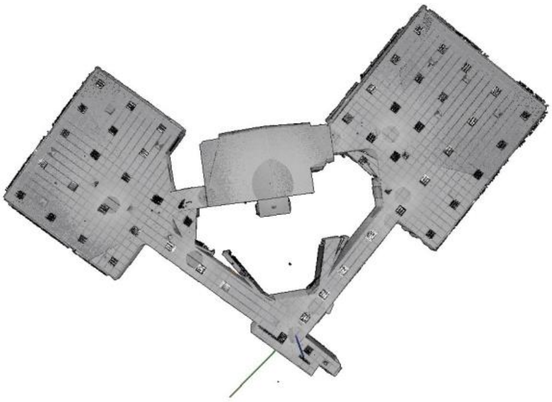

Figure 4. Riegl point cloud of the test area.

The Elios 3 was flown, following recommended mapping flight guidelines, by starting and ending the flight in the same location. The scan trajectory (flight path) can be seen in Figure 5. One entire loop of the office was undertaken as well as an additional small loop where the two corridors meet. The Elios 3 LiDAR Sensor (Ouster OS0-32) data was processed using **GeoSLAM Connect v2.1.0**, filtered to remove outliers, and exported in LAZ format (Figure 6).

Figure 5. Elios 3 Accuracy Test Flight Path.

Figure 6. Elios 3 point cloud of the test area processed by GeoSLAM Connect v2.1.0.

Test Results

Assessing Local Accuracy

Local accuracy was assessed by Plane-to-Plane analysis. The Normal Distances between the planes in the reference model and the planes from the Elios 3 with **GeoSLAM Connect** data are given in Table 1. The results show that all the comparisons fall within +/- 16mm, and the Mean Absolute Normal Distance between the Elios 3 and the Reference Model was 8mm.

Name	Normal Distance
Plane 1	6 mm
Plane 2	0 mm
Plane 3	-16 mm
Plane 4	-10 mm
Plane 5	-13 mm
Plane 6	-3 mm
Mean - Absolute Normal Distance	8 mm

Table 1. Local Plane-to-Plane Accuracy.

Assessing System Precision

The results of Range Noise Analysis calculated using the Standard Deviation of the comparison planes in the Elios 3 data are shown in Table 2. These results of Elios 3 precision analysis show the standard deviation of all the planes falls within 15mm and the Mean Standard Deviation was 8mm to 1-sigma.

Name	Standard Deviation
Test 1	7 mm
Test 2	7 mm
Test 3	8 mm
Test 4	6 mm
Test 5	6 mm
Test 6	15 mm
Mean Standard Deviation	8 mm

Table 2. Range Noise Precision.

Conclusion

Accuracy tests were carried out in a standard office environment with planar surfaces using a mobile mapping system, the Elios 3 with **GeoSLAM Connect**. The data was compared against a reference model created by an industry standard Terrestrial Laser Scanner, a Riegl VZ-400. The Elios 3 point cloud data captured was processed using **GeoSLAM Connect v2.1.0.** and the Riegl reference data was processed using RiScan Pro 2.14.1. Alignment and Accuracy computations were calculated using PolyWorks MRS2019 IR3.

Plane-to-Plane analysis showing local accuracy output a mean Normal Distance of 8mm between the planes in the reference model and the Elios 3 data processed with **GeoSLAM Connect**.

When assessing the system precision, the Range Noise results showed a mean Standard Deviation of 8mm to 1-sigma.

The results suggest that the Elios 3 with **GeoSLAM Connect** compares well against a traditional TLS and with the **ZEB Revo** and **ZEB Horizon**, which are leading mobile mapping systems in the market.

References

1 Ouster OS0-32 DataSheet: datasheet-rev06-v2p3-os0.pdf

2 Riegl VZ400. DataSheet: VZ-400_2017-06-14.pdf.

3 PolyWorks MRS2019 IR3: EssentialsPolyWorksInspector.pdf

4U.S. Institute of Building Documentation: USIBD Level of Accuracy (LOA) Specification Guide, 2016, available via https://usibd.org/

5GIM International: Exploring the State of Mobile Mapping, 2022, available via https://www.gim-international.com/content/article/exploring-the-state-of-mobile-mapping

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