MULTIPLE SENSOR PLATFORMS

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IV/3 Mapping from High Resolution Data

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ABSTRACT:

The purpose of this paper is to demonstrate the advantages of using multiple sensor platforms to improve the absolute accuracy of Airborne Laser System (ALS) and Mobile Laser System (MLS) data sets. Terrestrial Laser Scanners (TLS) are capable of superior point positioning accuracies compared to ALS or MLS Systems. In this research we utilized high precision - high resolution geo-referenced TLS scans as a platform to analyze and improve the positioning of geo-referenced ALS scan data. Our research revealed an improvement in registration method as well better statistical analysis of the data.

1. INTRODUCTION

Current methods that are used to determine the accuracy of ALS data require comparison of isolated ground control points as a basis of comparison for triangulated meshes (DEM-Digital Elevation Model) of ALS data. This contemporary method leverages a small number of isolated points to qualify millions of airborne/mobile Lidar points, which results in less accurate registration process. The new procedure utilizes millions of high precision TLS points to create a triangulated mesh and perform the least square fit adjustment to triangulated mesh produced by ALS/MLS systems. This yielded in significant improvement in absolute accuracy and traceability to control established by proven conventional means.

Although this procedure introduces ground based Lidar data which requires an additional amount of acquisition time, the exponential increase of common points results in faster and more accurate calculation of the least square fit solution. This increase in calculation efficiency enables faster confirmation of results and greater confidence in data, while maintaining traceability to the control points.

2. AIRBORNE LIDAR SYSTEM

Airborne Lidar Remote Sensing Platforms have been commercially used since the mid 1990s. Over the years Airborne Laser Scanning has matured and evolved. Modern ALS are capable of producing higher point densities and higher accuracies. Today Airborne Lidar Scanning is one of the most effective and reliable means of terrain data collection.

An Airborne Lidar System typically comprises of three major components: a Lidar instrument, GNSS receiver, and Inertial Measurement Unit (IMU). The Lidar instrument provides very accurate ranging information which is then post processed and combined with IMU and GPS trajectory data. The end result is an organized, georeferenced point cloud.

The quality of the point cloud data produced by ALS depends on several factors: GPS and IMU accuracy, Lidar ranging accuracy, System Lever Arms precision, extended GPS base lines, Boresight calibration. All of the above biases have to be taken into account when processing airborne data. Other systematic biases can be eliminated by carefully planning flight missions where PDOP, atmospheric conditions, and proximity of base stations on a project.

3. TERRESTRIAL LIDAR SYSTEM

Terrestrial Laser Scanners are comprised of a synthesis of technologies. They are the composite of rapid pulse lasers, precisely calibrated receivers, precision timing, high-speed micro controlled motors, precise mirrors and advanced computing capabilities. With this assemblage of technology comes an advancement to methods of metrology developed over the last few millennia. Along with the improvement of angle measurement, the fundamental component of a TLS is its ability to transmit and receive light, advancement in echo digitization, or waveform processing, becomes critical to TOF lidar accuracy. The Riegl VZ400 terrestrial scanner executes online processing of full waveform data, which maximizes ranging accuracy and minimizes waveform processing labor. This enabled the scanner to be located in difficult positions with low angles of incidence (> 10 degrees) to the objective while maintaining optimum point positioning.

4. EXPERIMENT METHODOLOGY

In our experiment we wanted to prove that the accuracy of Airborne LiDAR data can be further improved by using high accuracy high resolution Terrestrial LiDAR data.

The first step in our experiment was to obtain very high accuracy control that would comply with NGS specifications. After ground control points were established following NGS-59 as closely as possible, high resolution, high precision scans needed to be taken. We used Riegl's RiScan PRO TLS acquisition software to register terrestrial scans together. The mathematical model used to register scans was the Least Squares Resection method. In this method, measurement intensive scans, often exceeding 5,000 points, were acquired of 0.10m cylindrical targets which were positioned 2.050m above established control points. To ensure maximum vertical accuracy, 2.000m Snap-Lock fixed height rods were utilized.

After ground control data and TLS data has been acquired we had to acquire airborne LiDAR data. We first flew a Boresight mission this mission was used to obtain data to calculate Boresight misalignment values (RPY) between IMU and the laser instrument. After the Boresight site has been flown and Boresight misalignment values have been accurately calculated the test site has been flown with Riegl LMS-Q680i LiDAR scanner. Upon completion of the mission INS/GPS and LiDAR data has been processed and evaluated.

Finally TLS and ALS data has been merged together. First we performed QA/AC analysis that revealed slight misalignment between terrestrial and airborne data sets. We then performed Multi-station Adjustment procedure which adjusted airborne data to terrestrial data utilizing an Iterative Closest Point (ICP) algorithm.

5. EXPERIMENT RESULTS

Equipment Used in the experiment

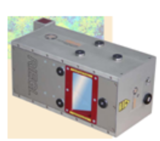
Parameter	VZ-400	LMS-Q680i
		
Measurement Range	1m - 500m	30m - 3000m at target reflectivity of 60%
Ranging Accuracy	5mm	20mm
Effective Measurement Rate	125 000 meas. per second	266 000 meas per sec
Scan Range	100 degrees FOV (adjustable)	60 degrees FOV (adjustable)
Scan Speed	3 lines/s to 120 lines/s	10 lines/s to 200 lines/s
Synchronization (2D line scan mode)	Integrated GPS synchronization	External GPS synchronization
Size	180mm x 308mm (diameter x length)	480mm x 212mm x 230mm
Weight	9.8kg (21.6 lb)	17.5kg(38.6lb)
Laser Safety	Laser Class 1 / Wavelength near infrared	Laser Class 3R / Wavelength near infrared

Table 1. Key specifications of the Riegl VZ-400 and LMS-Q680i scanners.

Other Equipment:

INS/GPS: Applanix POS AV510
Aircraft: Cessna 206
Base Stations: Topcon Hiper's, Trimble 5800, Leica Smart Rover

Ground Control

Control was established following NGS publication NGS-59 "Guidelines for Establishing GPS-Derived Orthometric Heights". Using six GPS receivers comprised of three Topcon Hiper's, two Trimble 5800's and a Leica Smart Rover. A total of six static observations of six hour intervals were performed over the course of two weeks. Three of these static sessions were performed to assess the NGS Benchmarks elevation integrity. Another three sessions were observed to establish newly monumented primary benchmarks immediately adjacent to the project. Redundant 40 minute rapid static sessions established 5 control points on each site. This resulted in a total of 6 independent sites with a total of 30 site control points. In all, over 500 baselines were computed to calculate the control values established for the project.

Terrestrial Data Acquisition

The objective of the terrestrial data was to serve as a platform for adjustment of the airborne lidar data. This means that earth-fixed object would be needed to serve as an intermediary between the two. We selected building rooftops to serve as a means of fixed reference. After establishing control via GPS, we scanned a total of 12 buildings for a total of 24 planar rooftop surfaces. Three of the six buildings selected were roofed with asphalt shingles, while the remaining three were roofed with tin metal material. Terrestrial LiDAR was acquired utilizing a Riegl VZ400 Time of Flight (TOF) Full Waveform scanner. Operating at 125kpps, the VZ400 enabled speedy data acquisition for time sensitive sites. Control values for the site were elevated with 8 fixed height carbon-fiber snap-lock rover rods held in position by 8 lightweight Raptor Tripods. These lightweight quick-release setups allowed expedient positioning for the VZ400 by positioning 10cm cylinders with reflective sheeting exactly 2.05m above the control points. In total, 25 scans summing 200 million points were acquired by RiScan PRO data acquisition software in a total of 225 minutes of scan time. Total acquisition time including travel, setup, breakdown of targeting equipment and acquisition of site access permission totaled approximately 8 hours. Registration was executed using a least squares resection method in RiScan PRO, the data acquisition software used for the project. In total, 22 scan positions were registered, averaging 0.004m standard deviation.

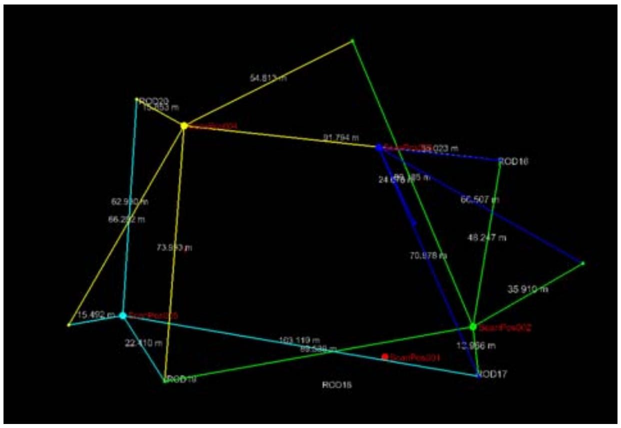


Figure 1. Illustration of resection control network.

6. AIRBORNE LiDAR DATA

Boresight Misalignment procedure

Angular misalignment of LiDAR and IMU axes has been know as one of the biggest error contributions in ALS. This misalignment between IMU and the LiDAR device can produce a significant error to the LiDAR point cloud. Riegl Boresight Misalignment procedure offers tools that remove this error by means of calculating RPY misalignment angles.

We flew 4 N-S opposing direction flight lines and 4 overlapping E-W flight lines at 1480ft @ 400 KHz PRR. The location of the Boresight was residential neighborhood with a significant number of homes with flat shingle roof tops. The Boresight misalignment procedure that we used found 104000 planar surfaces in which 5751 were used to accurately calculate RPY misalignment.

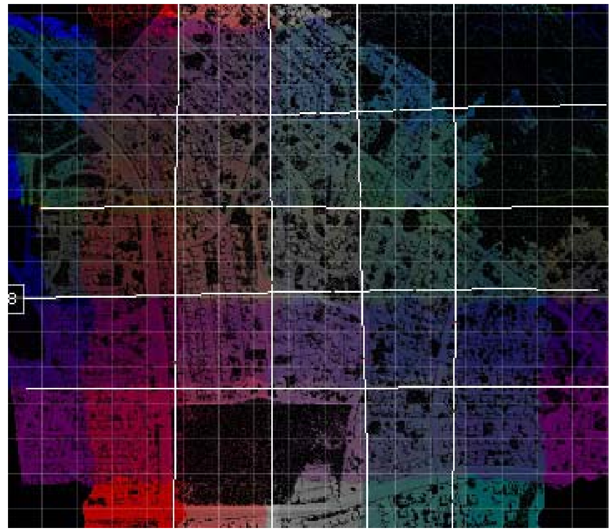


Figure 2. Screenshot of Boresight mission 8 flight lines single color

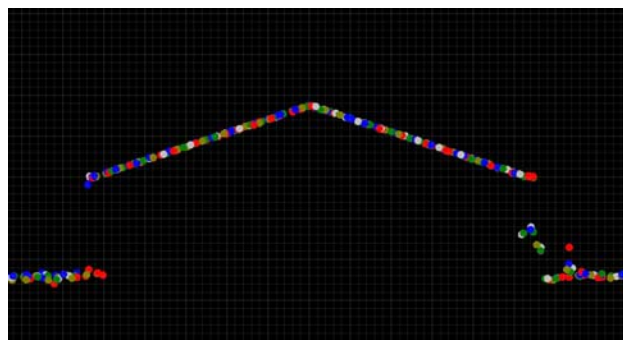


Figure 3. Four overlapping scans fitted together after Boresight Procedure

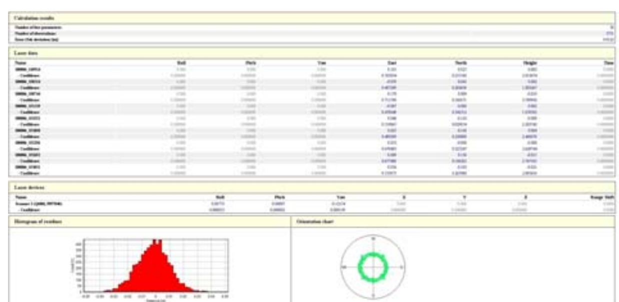


Figure 4: Boresight Report

Airborne LiDAR Data Processing

After data acquisition we processed the trajectory which yielded less than 1cm on average for RMS Northing Easting Down position.

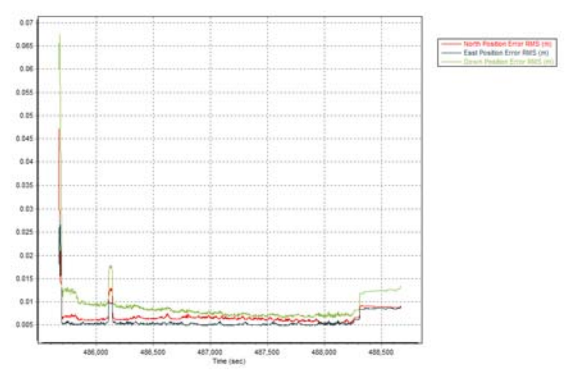


Figure 5. Northing Easting Down RMS(m) accuracy graph

We then merged LiDAR and trajectory together. We performed QA/QC on the LiDAR data and found that our results were 0.02cm standard deviation when compared between all individual flight lines.

ALS and TLS Data Fusion

After TLS and ALS acquisition, LAS 1.2 files were exported from RiProcess for airborne data and RiScan PRO for terrestrial data. These LAS datasets were then imported into a new project in RiScan PRO. To properly calculate a best fit solution, triangular meshes were created from the airborne and terrestrial data independently. Once triangulation was completed, we used RiScan PRO's MultiStation Adjustment tool, an Iterative Closest Point (ICP) algorithm, to adjust the airborne data to the terrestrial data. The terrestrial data's position was held constant and both the terrestrial and airborne data's orientation (roll, pitch, and yaw) were fixed, allowing linear translation of the airborne data.

The result of this ICP adjustment was a three-dimensional standard deviation of 0.0088m. A total of 11,578 triangles were matched to produce this result.

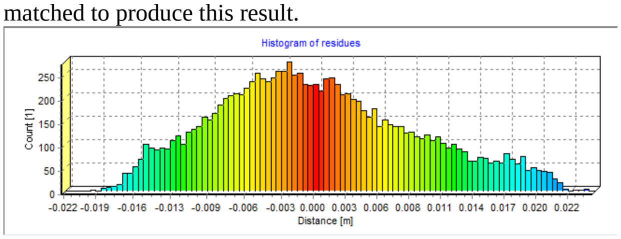


Figure 6. ICP Adjustment Residuals

Figure 7. Tin Roof Data Sample. Note: Airborne is White.

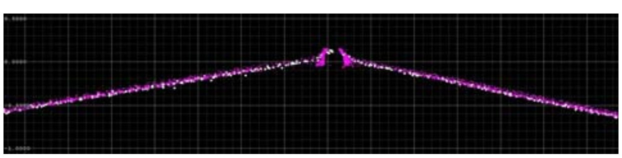


Figure 8. Profile view of merged dataset.

7. CONCLUSION

While the existing method of using isolated ground control points to validate airborne lidar has been shown to work for establishing vertical positions, there is a large level of positional uncertainty involved. The method demonstrated by this paper has been shown to be a viable tool in validating and adjusting airborne datasets. Utilizing the proven accuracy of terrestrial scanners in tandem with the reliability of fixed-earth objects such as rooftops has shown to be a powerful tool in adjusting and analyzing airborne datasets.

A brief examination of the time spent acquiring TLS data will show that the costs involved are surpassed by the benefit of achieving accurately constrained airborne data.

8. REFERENCES

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