Study Purpose

The purpose of this study is to assess a lower-cost mobile lidar system, along with a 360-degree spherical camera to develop a best practices workflow for use in beach corridor mapping. The mobile lidar system (referred to as the HiWay Mapper by LidarUSA) is integrated with a Velodyne HDL-32E rotating lidar sensor and a NovAtel Synchronized Position, Attitude, and Navigation (SPAN) IGM inertial navigation system (INS) consisting of a Sensonor OEM-STM300 inertial measurement unit (IMU), an onboard NovAtel OEM609 receiver, and a NovAtel 702-G2 Global navigation satellite system (GNSS) receiver.

This work performs a series of scan test to assess the following:
1. INS initialization procedure to improve trajectory post-processing with a local GNSS base station
2. Impact of scanner range on the accuracy of the resulting point cloud data
3. Impact of a ground control point (GCP) network on vertical accuracy of the point cloud data

Sensor

The HiWay Mapper system consists of a Velodyne HDL-32E lidar (San Jose, CA, USA), a NovAtel INS (Calgary, AB, Canada), and a FLIR Ladybug camera (Wilsonville, OR, USA). The Velodyne is a short-range, relatively low cost miniaturized scanner. Specifications of the Velodyne can be found in Table 1. The INS contains a Sensonor STM300 IMU (Horten, Norway) which is a small, lightweight sensor with 3 accelerometers and 3 gyroscopes. It collects at a data rate of 125 Hz and has integration capabilities with SPAN GNSS receivers. The NovAtel 702-G2 GNSS receiver is a dual frequency antenna designed to have a highly stable phase center, designed for movement. The FLIR Ladybug camera is a 360-degree camera with an accuracy of ±2 mm at a distance of 30 m (see Table II for more specifications). It can be synchronized with the Snoopsys system (Velodyne Lidar and NovAtel INS) and used to colorize the resulting point cloud.

Project Location

Data collection for the initialization procedure and the range test were conducted on the Texas A&M Corpus Christi (TAMUCC) campus. The scan with the ground control network was conducted on North Padre Island from Bob Hall Pier to Packery Channel. Scan locations can be viewed in Fig. 1.

Methodology

Initialization

The initialization procedure, used to align the INS and improve post-processing trajectory data, took place on the TAMUCC campus. The procedure was modeled after that those are presented in Li- darUSA Wiki and Solomon, Wang and Rizos (2012). The procedure is as follows:
1. Drive straight for 30 seconds
2. Stop and go with both left and right-hand turns 4.5 times
3. Figure 8 in one direction at least 4 times
4. Figure 8 in the other direction at least 4 times

Two scans were completed using this procedure, one with diligence, and one slowly and carelessly. IMU alignment times were then compared.

Range

The range test was completed to determine the scan cutoff distance. Although the Velodyne HDL-32E has an effective range of 100 m, it is important to determine the ideal point-cutoff distance in post-processing for desired accuracy. Seven scans were completed, ranging from 17 m to 103 m, the focus of which was a flat wall. These scans were then compared to a terrestrial lidar system (TLS) control scan completed using a Reigl VZ-4000 which has an accuracy of ±5 mm and an effective range of up to 600 m (Riegler, Horn, Austria, 1978).

Ground Control

The GCP test took place on the North Padre Island coast and also used to study the effects of hurricane Hanna. The sensor was mounted on the roof of a 4WD utility vehicle, pictured in Fig. 2. The ground control points (GCPs) consisted of black painted targets with a small, reflective target in the center (Fig. 3). A scan of ~4 km was completed from Bob Hall Pier on North Padre Island to Packery Channel and back. A total of 17 targets were laid every 300 m along the beach, alternating placement between one side of the beach, near the dune and the other side of the beach, near the water. These GCPs were then georeferenced with an Alhas NEQ (Septentrio N.V., Leuven, Belgium, 2000) connected to a real-time kinematic (RTK) network using virtual reference stations (VRS) broadcast corrections, at 5 second epochs. This system has the RTK performance of 0.6 cm + 0.5 ppm horizontally and 1 cm + 1 ppm vertically. 10 GCPs were used as control points, and 6 were used as check points. Three transects at the beginning, middle, and end of the project site were also georeferenced for use in the accuracy assessment. These natural ground points spanned from the dune line to the waterline total of 25 points were referenced.

Results

Initialization

The rigorous initialization procedure proved to have a quicker IMU alignment time than the slow procedure. A time of 35 seconds and 122 seconds were reported for each, respectively. This proves that dynamic driving is useful before performing a scan to assure good INS alignment.

Ground Control

The root mean square error (RMSE) was calculated to determine the vertical and horizontal accuracy of the scan with and without control, as shown in Table IV, where “No GCPs” in based on the residuals from the original scan, not corrected with GCPs and the “with GCP” is the scan corrected with GCPs and the checkpoints are used to verify the accuracy of the scan with GCP corrections. The results show that the use of GCPs make a difference in the overall accuracy of the point clouds, but much error still persists. The vertical accuracy was validated using the natural ground transects, shown in Table III. These results show that the vertical accuracy is improved with the GCPs but don’t explain the difference in vertical error. This must be checked and is mostly likely user error, as the ground targets used were difficult to select.

Conclusion and Future Work

In order to develop a best procedures workflow, it is important to implement a series of tests to include pre-scan, scanning, and post-processing methods. This project tested an initialization procedure, a range experiment, and a ground control experiment. More tests are needed to improve accuracy with GCPs, such as testing different types of targets, as this may be a major factor contributing to such a high vertical error. Future tests will build on the GCP network and refine results to include in a start-to-finish workflow with recommendations for using the HiWay Mapper in coastal environments.

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References


Fig. 3. Example of the GCP targets used for the post-Hanna scan.