3-2015

Integrating Industrial Laser Scanners for Small Vessel Operations

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Recommended Citation
V. Pradith, Pe'eri, S., Maddock, D., Oroshnik, D., Riley, J., and Murray, B., "Integrating Industrial Laser Scanners for Small Vessel Operations", US Hydrographic Conference 2015. 2015.

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Abstract

The NOAA Navigation Response Teams (NRTs) perform hydrographic surveys to support nautical charting updates for 175 ports of the United States Marine Transportation System. These include the identification of bathymetric and anthropogenic features that may pose a danger to navigation. In addition, NRTs respond to emergencies, speed the resumption of shipping after storm events, and protect life and property from underwater dangers. The spectrum of dangers occurs from natural features, such as rocks to anthropogenic objects such as piers.

Previous work conducted by the NOAA Office of Coast Survey have shown that survey-grade laser scanners can be used to remotely map features that are dangers-to-navigation. However, the justifications to purchase these systems are difficult since one system can be on the order of several hundred thousand dollars. An alternative solution is proposed through the use of economical industrial laser scanners. The capabilities of these systems can vary widely with range and angular resolution and require additional integration (e.g., translation into geographic space and timing considerations) into the network of sensors typical of vessels engaged in hydrographic operations. This paper presents evaluation work to balance cost versus performance using an industrial laser scanner into a hydrographic system. The laser scanner was evaluated in a laboratory setting at the Joint Hydrographic Center / Center for Coastal and Ocean Mapping (CCOM/JHC), University of New Hampshire (UNH) water tank facilities and aboard the R/V Coastal Surveyor (Portsmouth Harbor, NH). The results of the study include a first-order analysis of Velodyne's VLP-32E system and its target detection performance on piers, piles, air gaps and overhanging cables.

Introduction

The nature of hydrographic surveying in ports and emergency response operations are differently configured than that of open-ocean surveys. It is hard to create a survey-line plan before visiting a survey site due to various complexities. In addition to underwater features (e.g., submerged wrecks, rocks, obstructions and shoals), above water features also pose a danger to navigation (e.g., exposed wrecks, rocks, obstructions, piers, and piles) are omnipresent about the area. For large-scale charting (1:5,000 and larger), it is important to be able to differentiate features such as docks to separate the submerged bottom-fixed structure to the surface construction. In addition, floating-tethered features (e.g., buoys and moorings) are prevalent in these areas. The accuracy of the horizontal position and a tidally-referenced height of the bottom-fixed features is required at a decimeter (tenths of a meter) level for multi-scale charting purposes.

Currently, above water features are mapped using backpack mounted GPS equipment, handheld laser range finders, handheld compasses, digital point-and-shoot cameras, and data logging software (Wyllie et al., 2012). Such operations provide a reasonable first-order approximation to the location of the feature, however the result is a single measurement with a variable horizontal accuracy in the order of meters. In addition, the survey vessel is required to be stationary increasing survey time.

Over the past decade, NOAA has conducted two evaluation projects using long-range (maximum detection greater than 100 m) survey-grade laser scanners. The first project was conducted in 2007 using a Riegl LMS-Z420i laser scanner in Norfolk, VA (Brennan et al., 2008) and a second project was conducted in 2011 using an Applanix LandMark scanner in Norfolk, VA and Kodiak, AK. (Wyllie et al., 2012). Although both projects showed promising results, it was difficult to justify the hardware and software costs (> $100K) for integrating such systems onto survey vessels.

For routine hydrographic surveys in ports or mapping operations during emergency response incidents, it is important to have a laser scanner system that can operate at least 50 meters in an outdoor environment (splash proof, humidity and temperature) and meet eye-safety regulations. Also, the resulting point cloud must be able to resolve features at a spatial distance better than 0.25 meters. More recently, mid-range (i.e. maximum detection greater than 30 m and up to 100 m) industrial-grade laser scanners have become available for commercial use. These systems are splash resistant systems that can operate on small moving vessels such as cars, boats, and drones.

This paper presents the use of Velodyne's VLP-32E system as a survey tool on a Type II small-class survey vessel. The laser scanner interfaces directly with auxiliary systems (GNSS/ INS) using HYPACK's HYSWEEP module. In December, 2014, evaluation tests were conducted in laboratory settings at the Center of Coastal and Ocean Mapping - Joint Hydrographic Center at the University of New Hampshire (CCOM-JHC/UNH) water tank facilities and aboard the R/V Coastal Surveyor (Portsmouth Harbor, NH).

Survey configuration

a. Hardware and software overview

The specific make and model used in the evaluation tests was a Velodyne HDL-32E (Figure 1). This industrial-grade laser scanner includes 32 lasers and a rotating mirror scanner. The scanner generates a point cloud of up to 700,000 points per second with a maximum detection range of 80 to 100 m. The reported accuracy (one sigma), according to the manufacturer, is ±2 cm using a scanning rate of 10 Hz at a distance of 25 m from the scanner. The resulting point-cloud data is internally referenced. Internal microelectromechanical systems (MEMS) accelerometers and gyros provide for six-axis motion correction to the orientation and positioning of the laser ranges.

Although it is possible to perform absolute referencing using software development kit and a GPS time-synchronized (external signal), it is recommended to reference using available software currently found on survey vessels. HYPACK's HYSWEEP module was used as an interface between the laser measurements to the vessel's auxiliary systems (GNSS/INS). Thus, allowing the option to conduct calibration, data collection and data processing in concert with the in situ acoustic systems or any other survey devices.

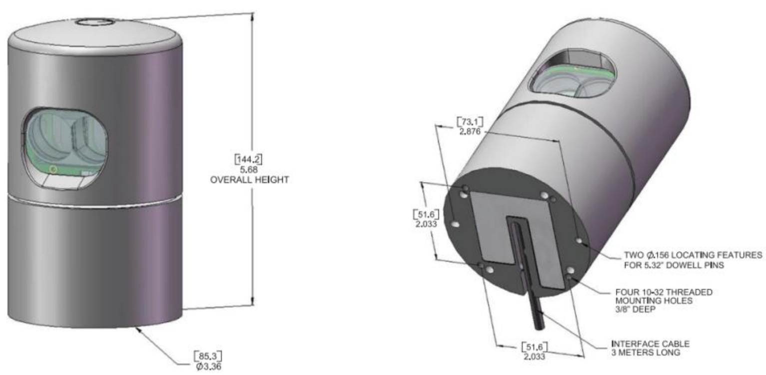

Figure 1. Schematic diagram of the Velodyne's HDL-32E laser scanner.

b. Laboratory work

In order to rank the different possible survey configurations using an industrial laser scanner, the system was evaluated in JHC/CCOM water tank facilities at UNH. The laser scanner was mounted on a cable-driven tow carriage that runs on beams stretching along the length of the tank (i.e., 30 m). The scanner operated at different survey configurations, while the carriage was traversing the tank at velocities ranging from 0.1 to 2 m/s. The laboratory work included a statistical evaluation of the laser scanner performance under following settings (Figure 2):

1. Vertical scanning in static mode at a frame rate of 5 , 10 and 20 Hz equal to 1200, 600 and 300 laser measurements per frame, respectively.
2. Vertical scanning in dynamic mode (0.5, 1.0, 1.5, and 2 m/s) at a frame rate of 10 Hz.
3. Horizontal scanning in dynamic mode (0.5, 1.0, 1.5, and 2 m/s) at a frame rate of 10 Hz.

c. Field survey

The field survey was conducted in Portsmouth Harbor in good survey conditions (i.e., sunny, calm waters with an air temperature in the low 50's F). The sensor was mounted on JHC's *R/V Coastal Surveyor*. An Applanix POS MV v4 system provided auxiliary data to reference the laser measurements. The survey was conducted along the Pisqutaqua River (Great Bay Estuary) up to Memorial Bridge in Kittery, ME and down to the lighthouse on New Castle Island, NH (Figure 3). Along the path, various above water features were mapped within different shoreline regimes.

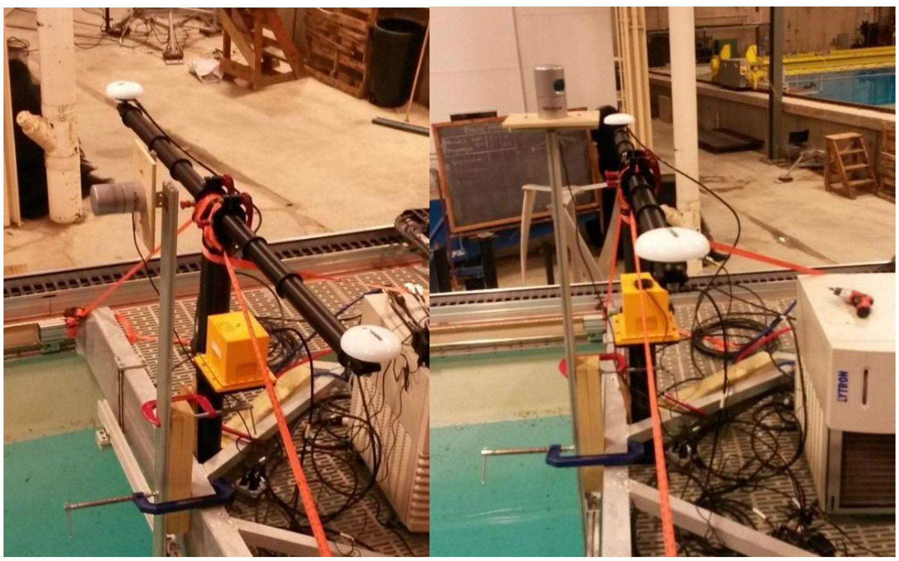

Figure 2. Laboratory setup of the laser scanner: (left) vertical scanning configuration and (right) horizontal scanning configuration.

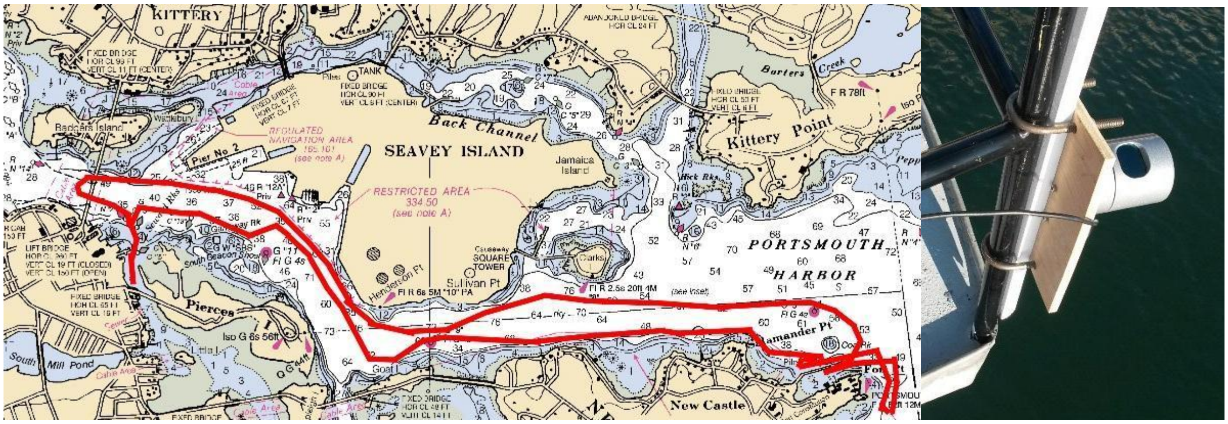

Figure 3. Field work using an industrial laser scanner: (left) Survey path of the mobile laser scanner survey overlaid on NOAA Chart 13823; (right) the laser mounted on the bow of the survey vessel (vertical scan mode).

Results

The laboratory work showed that repeated passes using the internally referenced point cloud provides a consistent horizontal and vertical positioning. It was also notice that the infrared laser (905 nm) is able to detect the water surface in the beams close to nadir. This water surface measurements can provide a tidally-reference surface to above water features. The laboratory results showed that the most suitable survey configurations for feature detection was a vertical scanning at frame rate of 5 Hz. A byproduct from the laboratory work was the ability to test different mounts. A plate mount with U-bolts was found to be the most flexible to mounting locations that are available on any given survey vessel (rails or on top of the pilot house).

Results from the field survey showed that the laser scanner can identify and map the following features:

1. Anchoring, lobster buoys, and moorings.
2. Aids-to-Navigation (ATON): buoys and towers.
3. Anthropogenic structures: piles, piers, walls, bridges.
4. Natural detached features: islands and rocks.
5. Natural contiguous features: shoreline.

The focus of this study is on ATON, anthropogenic structures, and naturally detached features. More importantly, this study seeks to improve the safety and efficiency of feature detection and mapping.

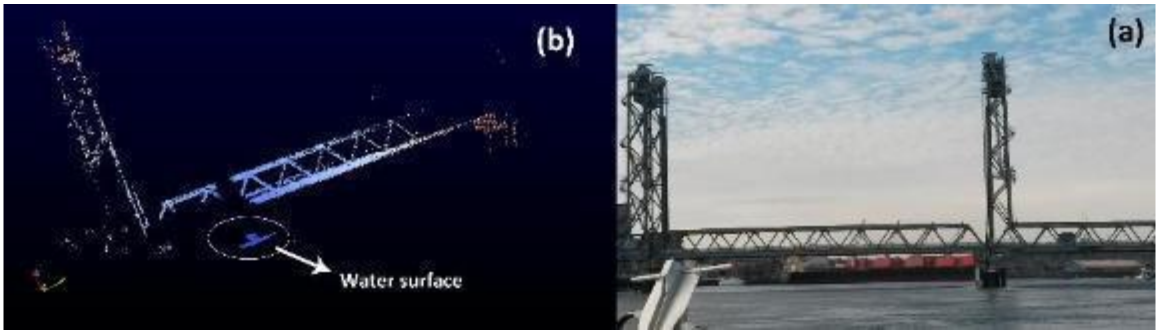

Figure 4. Mobile laser scanner results of the Memorial Bridge, Kittery, ME: (a) image of the bridge (12/1/2014) and (b) point cloud of 14 frames (scans) showing the bridge structure and the water surface.

Discussion and conclusions

The results present a proof-of-concept that industrial-grade laser scanners can provide an economic alternative to survey-grade laser scanners. It is important to note that more work is needed to decode the system's integration and calibration process along with the final product delivery to the end-user. After the point cloud dataset is processed, the deliverables should be simplified for hydrographic and charting purposes. Two potential deliverables are:

1. An S-57 attributed feature file of the horizontal location of the target with a tidally-referenced height following the feature attribution standards of the Hydrographic Specifications and Deliverables (HSSD., Section 8.2) detailing the Final Feature File. This method is currently compatible with the existing charting pipeline.

2. Output a modeled feature with a defined geometrical shape that can be imported into CAD or GIS software.

References

Wyllie, K., Froelich, G., Cove, K., and Hart, K. 2012. Process for Capturing Real World Features from 3D Laser Scanned Point Clouds, Proceedings in Canadian Hydrographic Conference (CHC 2012): The Arctic, Old Challenges New Approaches, Niagara Falls, Canada 15-17 May 2012.

Brennan, R., Canter, P., Van Rens, J. 2008. Surface Imaging Capabilities on Marine Hydrographic Vessels, Hydro International 12(1):

NOAA National Ocean Service Hydrographic Surveys Specifications and Deliverables. 2014.