

New Method for Combining Optical and Acoustic Mapping Products

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14. ABSTRACT Current mapping and charting methodologies requires separate vertical datums to be used for optical (topographic) and acoustic (bathymetric) datasets. Our objective was to develop a new mapping capability that would allow for the seamless combination of acoustic and optical mapping products. We hypothesize that a single, common datum between the datasets can be achieved by using a shared inertial measurement unit (IMU) to apply navigation and attitude corrections to both datasets. We concurrently collected two datasets using a topographic lidar unit for the optical data and a bathymetric dual-head multibeam echosounder (MBES) for the acoustic data. Navigation and attitude data were collected and provided to both optical and acoustic datasets via a single Applanix POS/LV IMU. The study included successful bench testing of the full equipment setup and a successful land-based proof-of-concept test for a scaled-down setup.					
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NEW METHOD FOR COMBINING OPTICAL AND ACOUSTIC MAPPING PRODUCTS

1. OBJECTIVE

The U.S. Naval Research Laboratory (NRL) conducted research to facilitate a better understanding of sediment transport dynamics in the swash zone, the interface between land and sea. The morphodynamics of this area are difficult to quantify; firstly, the physical processes of this domain make it difficult to collect quality data. Secondly, bathymetry and topography typically are collected in differing vertical datums; bathymetry typically is referenced to a tidal datum such as mean lower low water (MLLW), while topography is referenced to the geoid or to the ellipsoid. The different datums pose a technical challenge when trying to create a single, combined product that simultaneously maps adjacent bathymetry and topography. To overcome the challenge, we propose that optical and acoustic data be collected simultaneously and referenced to the same vertical datum. The process will allow for the creation of a seamless surface representing both bathymetric and topographic data without introducing errors via datum transformations.

2. RESULTS

2.1 Equipment Setup

The equipment used in this research included the following: a dual-head Reson SeaBat T20P multibeam echosounder (MBES) in conjunction with an AML SmartX sound velocity probe (SVP) for acoustic data collection, a terrestrial Riegl VZ-1000 lidar scanner for optical data collection, and an Applanix POS/LV 520 inertial measurement unit (IMU) for navigation, attitude, and timing data collection. The POS/LV was used in conjunction with a wheel-mounted distance measurement instrument (DMI) and two GPS antennas. Bench testing was conducted using the full equipment setup to verify research viability before field testing.

Figure 1 shows the bench test setup. The lidar unit is on the right-hand table along with the control unit for the IMU. On the desk are the two laptops controlling the MBES and lidar systems. To the left of the laptops are the two portable sonar processors for the MBES transducers. The MBES transducers and the SVP were placed into buckets to prevent overheating and degradation during testing. The IMU and GPS antennas were outside and are not shown, while the DMI was not used for the bench test. Figure 2 is a wiring diagram detailing the data and power connections between all of the systems.



Fig. 1—Bench test of the MBES, lidar, and positioning systems (Hode, Phillip, Braithwaite III, Key, & Calantoni, 2019)

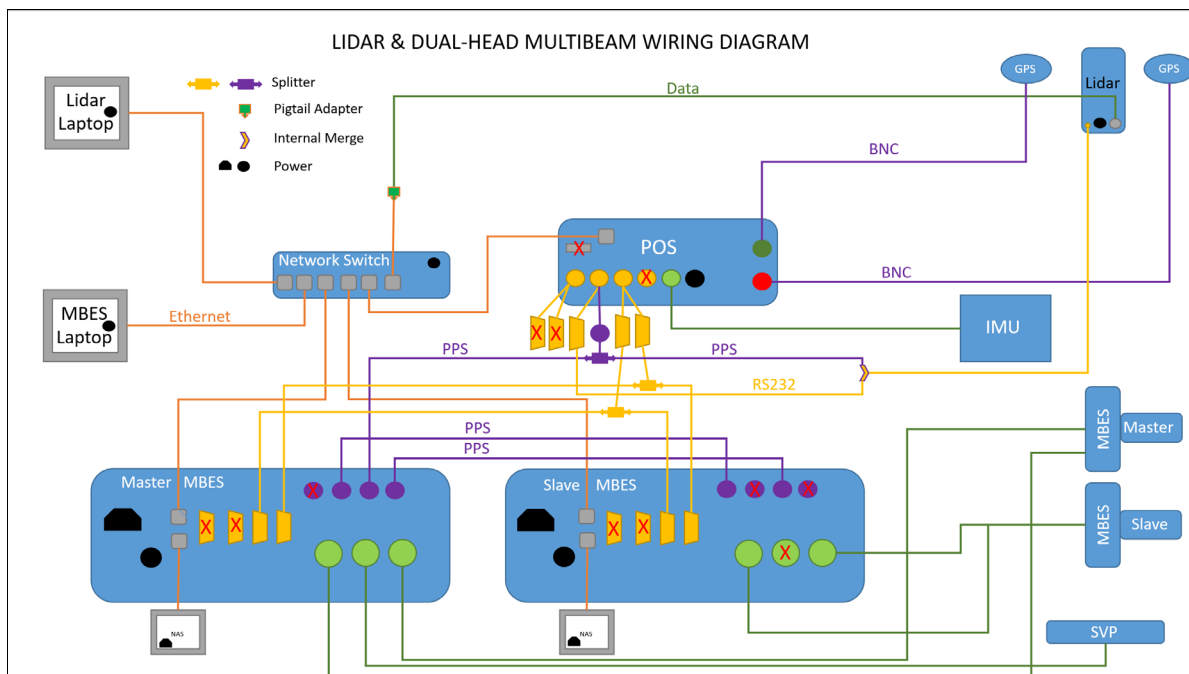


Fig. 2—Wiring diagram for the MBES, lidar, and positioning systems

2.2 Proof of Concept with Single-Head Multibeam

A proof-of-concept experiment was conducted as a cost- and time-saving measure. Due to power and space constraints, the test was conducted with a single-head MBES configuration instead of a dual-head configuration. As shown in Fig. 3, the lidar, IMU, and GPS antennas were rigidly mounted onto the cab of a truck. The MBES transducer was placed into a water-filled bucket and secured in the bed of the truck. Cabling was run into the cab of the truck to the portable sonar processor (PSP), the IMU control unit, and the acquisition laptops. Additionally, the DMI was attached to the rear driver's side wheel of the truck in order to provide more accurate positioning data. The XYZ offsets between the IMU, the DMI, and the MBES transducer were measured using a tape measure. The XYZ offsets of between the lidar, the IMU and the GPS antennas were established by the manufacturer of the framework.



Fig. 3—Proof-of-concept test with single-head MBES, lidar, and IMU (Hode et al. 2019). At left, the MBES transducer head is in an orange bucket secured in the bed of the truck, with the lidar-and-IMU setup secured to a roof rack on the cab of the truck. At right is a side view of the lidar-and-IMU setup on the cab of the truck, with cabling for all of the instruments running through the rear windows.

A boresight calibration was completed in order to find the roll, pitch, and yaw offsets between the lidar system and the IMU systems. Unaccounted-for offsets between the lidar and IMU systems led to horizontal, vertical, and angular offsets between repeated lidar scans. The boresight calibration was done before the MBES was secured in the bed of the truck to reduce the possibility of damage to the transducer. The procedure for the calibration was to drive the truck along a 1-km stretch of straight, flat road with the lidar scanning off of the passenger side at a 45-degree angle. This was repeated an additional four times, with the lidar angle incrementing to 60, 90, 120, and 150 degrees. A statistical analysis was performed on the scans using Riegl's RiProcess software in order to mitigate and reduce the scan misalignment. Table 1 shows the resultant roll, pitch, and yaw boresight calibration values for the lidar/IMU system. (Rieger, Studnicka, & Pfennigbauer, n.d.)

Table 1 — Lidar Boresight Calibration Values

	Roll	Pitch	Yaw	Standard Dev.
Offset (degrees)	-0.02078	0.06286	0.09438	0.0177
Confidence (σ)	0.000126	0.000194	0.000263	

Concurrent optical, acoustic, and navigation data then was collected circumscribing the US Naval Research Building 1005 at Stennis Space Center in Mississippi. Both the acoustic and optical systems successfully recorded data and the processed results were georeferenced correctly using the navigation data. Figure 4 shows a bird's-eye view of the combined lidar and MBES data overlaid on a satellite photo of the surrounding area. Figure 5 shows a vertical profile of the interface between the MBES data and the lidar data illustrating the roughly 1-m vertical offset between the two datasets. This offset approximately matches that measured in situ with a tape measure between the MBES transducer in the bed of the truck and the lidar unit on top of the truck cab.

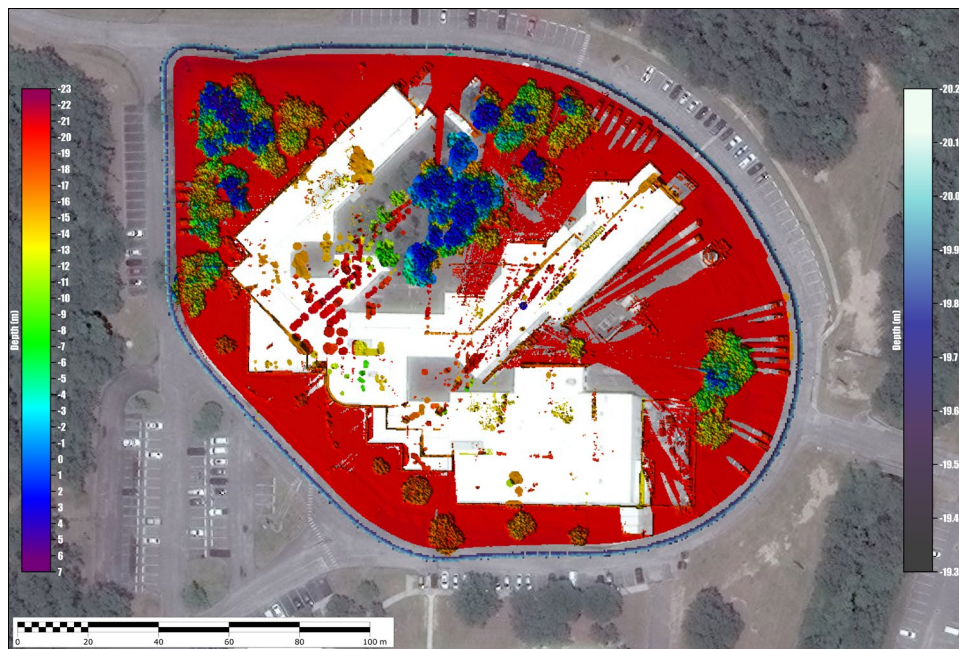


Fig. 4—Bird's-eye view of lidar (left color bar) and MBES (right color bar) data of the Naval Research Building 1005, Stennis Space Center, Mississippi. The MBES data consists of the blue-shaded line circumscribing the dataset, and the lidar data is inside the MBES data (Digital Globe, Inc., 2019; Hode et al. 2019).

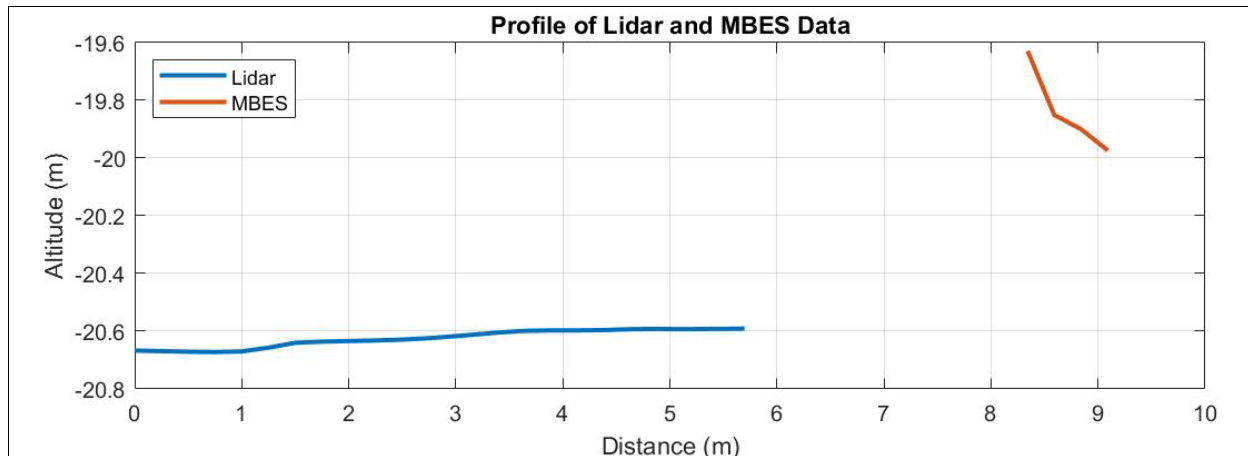


Fig. 5—Vertical profile of interface between lidar (blue) and MBES (orange) data with altitude referenced to the geoid (Hode et al. 2019)

3. FUTURE WORK

3.1 Proof of Concept with Dual-Head Multibeam

A second proof-of-concept test will be conducted utilizing the full experimental setup, to include the dual-head transducer and SVP system, along with all of the initial proof-of-concept components. An alternative power source will be secured in the bed of the truck in order to provide an additional power source for the two MBES units.

3.2 Field Testing

The entire system, including both MBES sonar heads, will be installed on a vessel and a full dataset will be collected, processed, and analyzed. Ideally, the instruments will be installed in a rigid configuration that can be replicated easily on other vessels of opportunity, negating the need for repeated vessel configuration surveys.

4. NAVAL RELEVANCE

Typical topographic and bathymetric survey operations are conducted separately from one another. The result of this is two separate datasets, most often referenced to different geodetic vertical datums, as topographic surveys are usually referenced to the ellipsoid and bathymetric surveys to a tidal datum. The existing state of the art introduces arbitrary errors into the data when combining adjacent topography and bathymetry, in addition to increasing the man-hours needed to collate the data into one complete set. Further, equipment such as the IMU, the GPS antennas, and the data acquisition computers are duplicated, which increases operational costs.

By concurrently collecting topographic optical and bathymetric acoustic data, we are able to reduce the amount of survey operations and man-hours needed to collect the data. The optical and acoustic data collected will be referenced geodetically to one vertical datum instead of two, simplifying data-processing operations and limiting the amount of errors introduced into the datasets via datum transformations. Operational costs can be lowered further by having the lidar and the MBES share acquisition and geodetic referencing equipment.

5. CONCLUSIONS

Based upon the successful bench test and land-based proof-of-concept operation, it was determined that concurrent collection of optical, acoustic, and navigation data is viable, and field operations have been planned for later this year utilizing the instrument configuration (Fig. 2).

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