Creating a Seamless Model of the Littoral and Near Shore Environments

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Abstract

Ports and harbours have long utilized multibeam sonar to model the surface below the water line, providing data for, amongst other applications, charting, construction, monitoring and habitat mapping. The mapping of adjacent near shore structures is often done on a much sparser basis using time consuming conventional land survey techniques. A marine vessel affords a unique perspective from which to capture these near shore structures and topography, providing a view point impossible from the land or the air.

This paper will catalogue the experiences gained to date in collecting simultaneous LiDAR, georeferenced video and multibeam data from hydrographic survey vessels operating in a typical inshore environment, where multipath and GPS outages are common. It will show the eye-catching images obtained, and explore the opportunities in marine imaging. We highlight the challenges encountered which, in addition to the GPS environment, included accurate timestamping and boresighting of the data.

Combining the robust and accurate georeferencing and motion compensation afforded by POS MV, together with the point cloud data from LiDAR and multibeam sonar, a seamless model of the port environment, both above and below the water line can be built up. This data set has a multitude of potential uses; in planning, security, maintenance and monitoring to name but a few examples, and this paper seeks to help define these new markets.

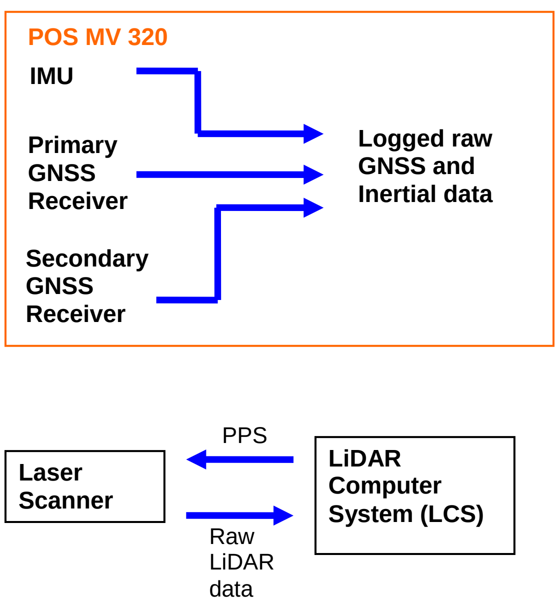
Introduction

Ports and harbors have long utilized multibeam sonar to model the surface below the water line, providing data for, amongst other applications, charting, construction, monitoring and habitat mapping. The mapping of adjacent near shore structures is often done on a much sparser basis using time consuming conventional land survey techniques. A marine vessel affords a unique perspective from which to capture these near shore structures and topography, providing a view point impossible from the land or the air.

This paper will catalogue the capture and analysis of simultaneous LiDAR and multibeam sonar data from various marine survey vessels, often operating in busy port environments where cranes, other vessels, bridges and dock side structures provide for a challenging environment in which to position the remote sensing equipment. Using a post processed, tightly coupled aided inertial navigation system for georeferencing and motion compensation provides the optimal position and orientation solution, even in these difficult areas.

Data Acquisition

Point cloud data to create the images shown in this presentation were collected on various marine survey vessels. Such platforms typically acquire multibeam echosounder data in order to produce a georeferenced point cloud of the seabed and other structures below the water surface. Hydrographic Surveyors are therefore very familiar with manipulating and interpreting point cloud data acquired from a mobile platform. This provides a useful synergy with the LiDAR data, where many of the same software tools typically used for analysis of multibeam data are ideal for imaging the combined point cloud.



Acquisition Workflow

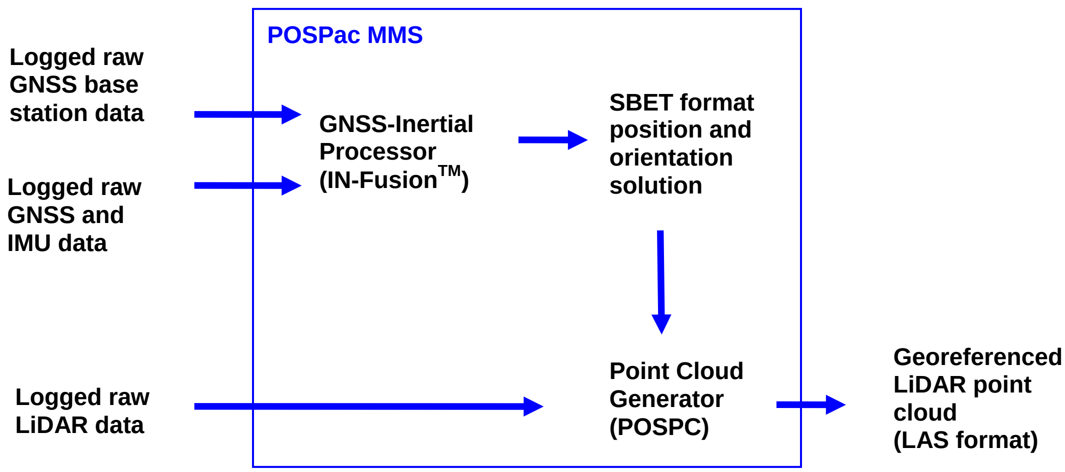
Raw LiDAR, GNSS and Inertial data were logged and, importantly, precisely time tagged for later post processing. LiDAR data is acquired by sending a 1PPS pulse (generated by the onboard GNSS receiver within the acquisition computer) to the laser. This triggers the internal counter to restart and the raw data is then transmitted via Ethernet to the acquisition computer, where a microsecond accurate time tag is applied.

GNSS and Inertial observables were also logged and accurately time tagged for processing.

Processing Methodology

Once logged, the raw inertial and GNSS observables are imported into POSPac MMS, Applanix' aided inertial post processing software suite. Together with satellite observations from a network of nearby GPS base stations, a tightly coupled aided inertial position and orientation solution is computed. This provides a robust and accurate source of georeferencing information known as the Smoothed Best Estimate of Trajectory (SBET).

The SBET is then used to provide georeferencing and motion compensation to the raw LiDAR data acquired during the survey. This is achieved using the POSPC (Point Cloud) module of POSPac MMS. The precise timing information inherent in both the SBET and LiDAR data ensure that an optimal solution is produced.



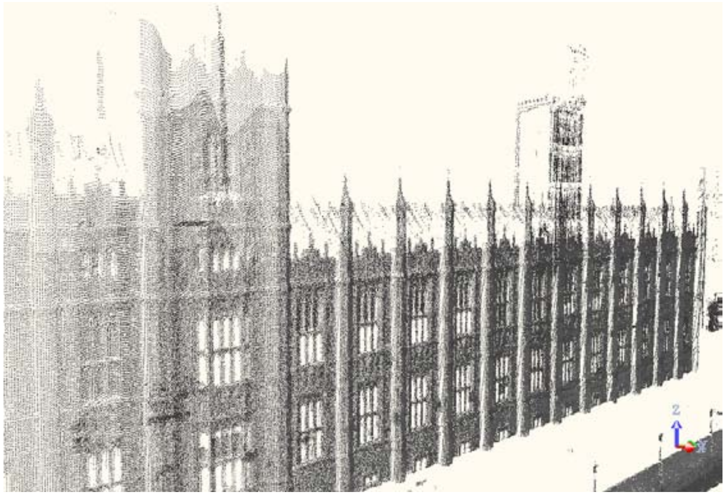
Processing Workflow

Case Studies

Case Study 1: Central London

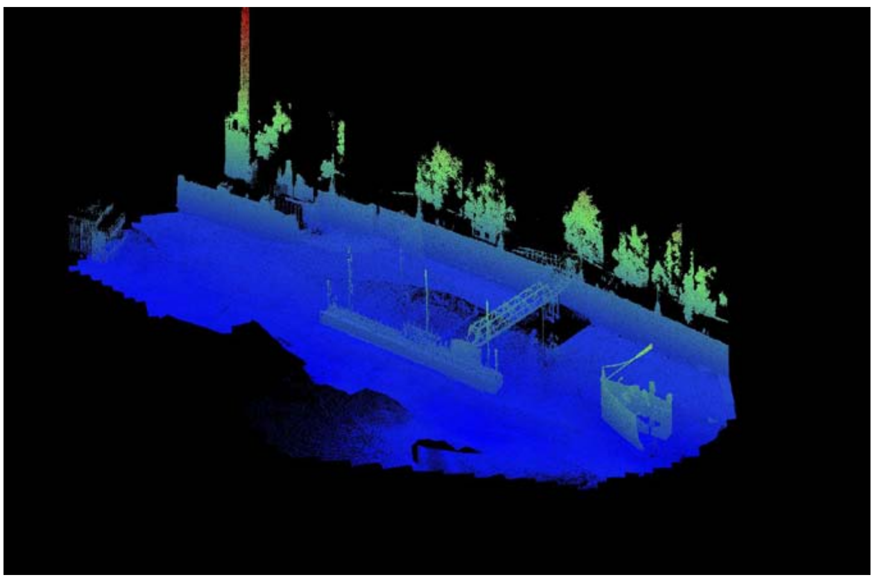
The Port of London Authority is charged with ensuring navigational safety and port security along the tidal river Thames, encompassing more than 95 miles of river. Three survey craft are operated by the PLA Hydrographic Service. *Galloper* is a shallow drafted catamaran equipped with a Reson 7125 multibeam sonar and an Applanix POS MV 320 aided inertial navigation system. As the smallest of the PLA survey fleet, it is ideally suited to operate in the shallowest and most restricted areas of the Thames.

The laser scanning and acquisition system described previously was deployed on *Galloper* in order to undertake a simultaneous survey of the river bed, banks and near shore structures. Surveying in central London afforded the opportunity to capture images of such iconic structures as the Palace of Westminster (also known as the Houses of Parliament). The clock tower housing "Big Ben" is clearly visible, as is the world famous architecture of the palace itself.



Palace of Westminster, London

The second image shows the combined bathymetry and LiDAR point cloud in an area surrounding Cleopatra's Needle, immediately down river from the Palace of Westminster. This was an especially challenging area to survey due to bridges, river traffic and other obstructions, but ideally illustrates the typical port environment.



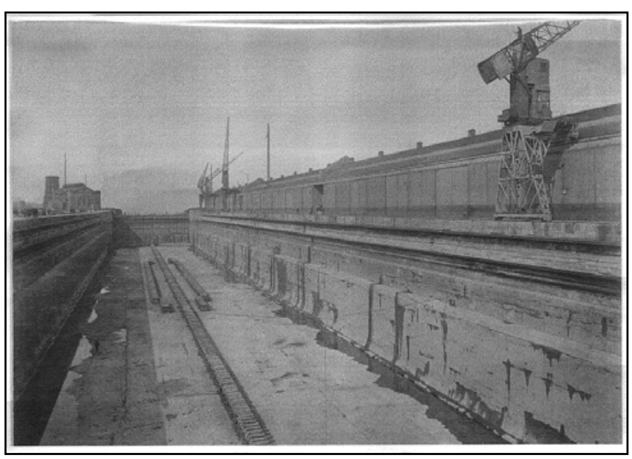
Merged Bathymetry and Laser Point Cloud, Cleopatra's Needle, London

Case Study 2: Port of Liverpool

As part of their ongoing survey work, the Port of Liverpool, a part of the Peel Ports Group, saw a need to survey the condition not only of the seabed, but also the quay walls and dockside structures.

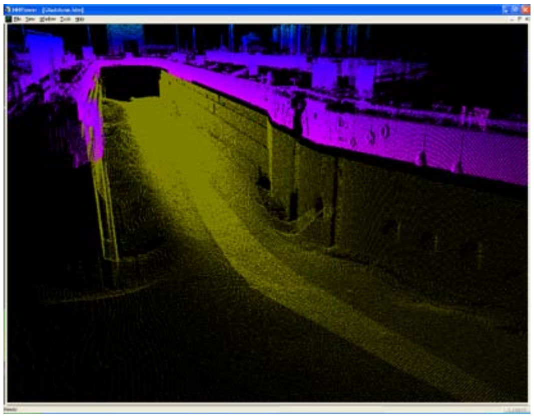
The Port of Liverpool survey vessel *Royal Charter* is equipped with a Reson 8125 multibeam sonar and Applanix POS MV 320 aided inertial navigation system. Using the same equipment utilized in London, the LiDAR and acquisition system were installed and a survey of Gladstone dock undertaken.

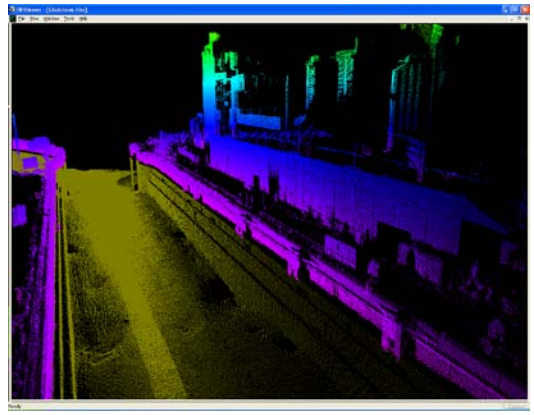
Conceived to handle the largest ships of the age, the construction of Gladstone Dock by the Mersey Docks and Harbour Board commenced in 1909. By 1913, the graving (dry) dock was complete and provided a facility 1050 ft long by 120 ft wide, large enough to accommodate the largest transatlantic liners of the age.



Gladstone Graving (Dry) Dock

The multibeam and laser data were combined in order to produce a seamless point cloud model of the dock. Some examples are shown below, where the yellow coloured surface is the multibeam data and the purple through green data is from the laser.





Combined multibeam and LiDAR images of Gladstone Graving Dock, Port of Liverpool

Case Study 3: Harbor Refuge Light, Delaware Bay

Harbor Refuge Light is located on a breakwater at the entrance to Delaware Bay. Access is difficult and dangerous, and, in order to evaluate erosion under the light, a laser scanner was deployed on a survey vessel belonging to the US Army Corps of Engineers, Philadelphia District. A multibeam and side scan sonar survey of the light base and jetty had been undertaken two years previously but, in order to evaluate damage and estimate accurately the materials required to affect a repair, a georeferenced point cloud of the area above the water line would be invaluable.

In this case, a LiDAR system was deployed to create and, in conjunction with the georeferencing information from POS MV 320, the point cloud data illustrated in the following images was created.

Harbor Refuge Light, Delaware Bay

Not Just a Pretty Picture

Although it is clear from the preceding sections that some stunning images can be obtained given the unique perspective offered by a survey vessel, manipulating the point cloud data in a way which adds value is the next important step.

Mensuration, the measurement of angles, distances and areas of geometric figures, is a primary function applied to georeferenced point cloud data. Point cloud processing and visualization packages contain tools for interactively making such distance and area calculations within a given data set. The precision of this measurement will depend on the quality of the data acquired. Measurements can be sub-centimeter in a relative (and sometimes absolute) sense. Engineers, construction planners and marine operators will make use of these measurements in the planning and execution phases of construction projects. Environmental planners, security professionals, harbor managers, coast guards and anyone with an interest in the near shore will find value in this data.

The three dimensional nature of the point cloud data derived from LiDAR measurements make volume calculations possible. Hydrographic surveyors routinely measure volumes of dredged material using point clouds and surfaces derived from multibeam sonar data. Dredgers are often paid on the basis of these volume calculations and it is therefore important to make an accurate calculation. These same techniques can now be applied to dredged materials being used for land reclamation projects or, indeed to any material stored in bulk for import or export. This is a significant improvement in efficiency when compared to the sparse nature of current measurements.

Models of coastal features and virtual representations of near shore structures which have been imaged from survey vessels can be put into the hands of project engineers and offer great value. Engineers can interact with the data in ways which allow for significant efficiencies in the planning and design phases of offshore and coastal construction or monitoring projects. A key function required is the ability to transform LiDAR point cloud data into CAD formats which are routinely used by project engineers. Most modern processing tools have this capability. Ships at dock can be imaged from a survey vessel and perspectives not usually available from land can be made available. All objects can be loaded into CAD packages with rich and powerful tool sets routinely used by engineers.

Automatic classification of coastal and marine infrastructure is also possible using a combination of LiDAR and photo imaging. By measuring their LiDAR reflectivity signature, coastal signage, buoys and other objects can be automatically identified and georeferenced. In addition, any ongoing changes in location or reflectivity of such objects may be extracted from repeat surveys. Change detection is an important tool for security and law enforcement organizations, enabling reliable and efficient monitoring of port environments. For environmental applications, the monitoring of changes in dykes and levees is vital for flood prevention, and LiDAR derived point clouds are ideal for this application.

Surface imaging from a marine platform is an emerging application. Although the “wow factor” has been considerable due to the stunning nature of the visual imagery, the challenge which lies ahead is to routinely extract value, making the data acquisition a viable economic proposition.

Summary and Conclusions

It has been shown that a marine vessel provides a unique platform from which to survey items both below and above the water surface. Robust georeferencing and motion compensation from an aided inertial navigation system enable the production of precise point cloud images from a combination of multibeam sonar and laser scanning equipment. This allows the surveyor to realize the full potential of these complementary technologies, producing data which has a multitude of potential applications in, for example, dredging, land reclamation, environmental monitoring, port security and bulk inventory management.

Acknowledgements

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