Autonomous Onboard Hydrographic Data Processing

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Abstract — During a traditional hydrographic survey, data can be acquired, accessed and processed by personnel working on the vessel or launch. Improved data processing tools have reduced the ratio of acquisition to processing time significantly in the past 10 years, despite an increase in the quantity and quality of data points available from modern sonars and sensors.

The improved performance of the bathymetric sonars and their associated ancillary sensors (motion, position etc.) has allowed surveyors to identify smaller targets with higher resolution than ever before. In addition, the physical size of these sensors has decreased, allowing deployment on platforms previously inaccessible by survey teams. The platforms used for acquisition have improved autonomy with Autonomous Underwater Vehicles (AUVs) and Autonomous Surface Vessels (ASVs), along with extended mission times driven by improved battery technology.

Hydrographic survey platforms are increasingly becoming autonomous or semi-autonomous due to the benefits that these platforms offer. Lower capital and operating costs, the ability to work undetected and closer to the intended target and multiple unit operation are just some of the benefits that can be exploited by the operator.

AUV technology has allowed for the development of smaller vehicles that are able to work in the shallow waters of the littoral, with a lower build cost allowing the deployment of several units for a single mission. AUVs have also been improved by battery power technology, allowing for extended mission times. A good example of a current program is the US Navy's Large Displacement Underwater Vehicle (LDUUV) which is anticipated to have an endurance measured in weeks rather than hours.

ASV development has been significant, with the challenges associated with navigating a surface vessel autonomously being addressed as a priority in the maritime community. The advantages of the ASV is the improved bandwidth that above water communications offers, allowing for real time transmission of data to the unit controlling the vehicle. Improvements in renewable energy sources such as solar, wind and wave power have meant that it is possible to operate an ASV for extended periods of time, and the decrease in platform cost has allowed for several units to be used in unison to gather intelligence over a large area.

The increased use of autonomous survey platforms has resulted in the ratio of acquisition to processing time has becoming a mission limiting factor again. Without human interaction in the real-time feedback loop, the platform must gather the data and await post-processing when it is recovered. This method has significant disadvantages, most notably a lack of assurance that the data collected is within the required specification and an increased turnaround time before the platform can be re-deployed.

On manned survey platforms significant time is often spent at the end of the survey conducting batch processing tasks such as conversion of data and running automated data cleaning algorithms. By performing these tasks at the end of the survey on a complete and large dataset, the processing times can be lengthy and this impedes the surveyor-in-charge's ability to make decisions for the subsequent survey plan.

This paper will describe a new software based method of acquiring and processing data autonomously in near real time whilst the survey is underway and look at the benefits that can be gained from using this method.

Keywords— Autonomous, Hydrographic, Data Processing, Multibeam Echo Sounder, Onboard

I. INTRODUCTION

In the early days of hydrographic surveying, soundings were carried out manually and plotted as they were acquired. This low data rate proved to be manageable; typically recording took the same or less time than the acquisition of a leadline sounding. As acoustic means were employed the data rate was increased, but mitigated by the use of recording paper that could be analyzed after the survey. However, the introduction of commercially available multibeam echo sounder systems and airborne laser systems in the late 1970s introduced data rates that were an order of magnitude larger than what was previously seen, and the acquisition to processing ratio was skewed towards longer processing times. This lead to increased use of computer aided processing, algorithms such as CUBE (Combined Uncertainty Bathymetric Estimation) and software such as CARIS HIPS (Hydrographic Information Processing System) to re-balance the acquisition to processing ratio.

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In the 21st century, we are seeing an increased focus on autonomy in the hydrographic survey field. The benefits are clear; faster setup and deployment, lower operating costs and the ability to deploy several units that can be monitored centrally. Initially these units were of limited duration, so any data gathered could be processed upon recovery in a short time span then the unit returned to continue surveying. As battery and energy production systems (solar, wind, fuel cell) improve, the mission time of these systems is increasing. Whereas this increase is beneficial to the operator, one of the major issues is the data bottleneck that is generated by longer missions.

II. THE CHALLENGE OF DATA VOLUMES

The technological development of sensors, traditional survey launches and unmanned platforms has meant a greater quality and quantity of hydrographic data available to the surveyor, but with this comes a large processing load to intelligently parse millions of data points into a handful of meaningful data. Although focused on mine warfare hydrographic data acquisition, the US Navy have already identified this challenge in their Unmanned Systems Integrated Roadmap:

> *5.5.3.2 Data processing enables the transmission of a reduced amount of data like beam-formed sonar images instead of raw, stave data, without compromising quality. Not only is there* ***a need to use preprocessing to reduce the amount of data transmitted****, but also automated target recognition enables target discrimination, i.e., reporting contacts of interest instead of sending entire images for human interpretation.*

US Department of Defense; Unmanned Systems Integrated Roadmap FY2013-2038 (14-S-0553)

The challenge is all the more relevant for systems such as airborne LiDAR, where the speed of sounding and acquisition platform (manned or unmanned aircraft) result in a very large dataset acquired over a short period of time. An additional challenge here is the relatively high cost of the platform to operate – the need to make decisions based on the processed dataset in a timely manner before the next tasking is often critical.

For multi sensor oceanographic platforms, often the bathymetric data proves to be the largest dataset and typically requires cleaning before it can be used effectively in conjunction with other sources of data for modelling purposes. Sensor data from Acoustic Doppler Current Profilers, for example, can be vertically draped in a 3D environment fairly simply from the raw data source, however the bathymetric surface within that view typically requires a great deal more manipulation from raw data to usable product.

The challenge of large data volumes acquired during a hydrographic survey results in two main issues:

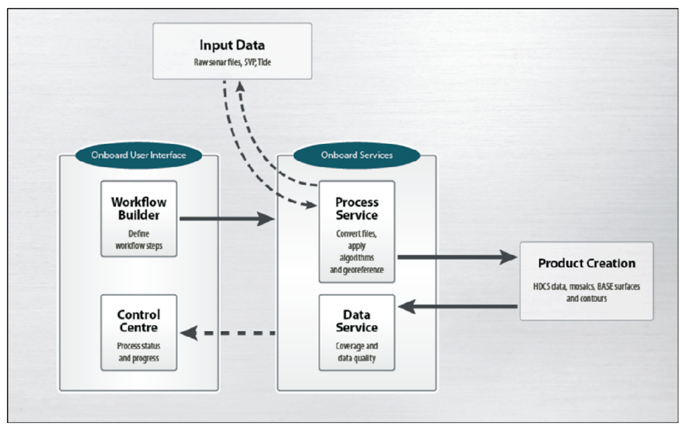
A. Without a software to conduct some or all of the preprocessing of the significant amounts of sensor data that is available on recovery of the vehicle, there is a time lag between platform recovery and product delivery.

B. The second issue that is brought about by this time lag is the ability for the surveyor to make a decision whilst the survey is taking place. A survey vessel that deploys several autonomous and/or manned vessels to survey a large area often has to wait for each mission to be completed before access to a meaningful dataset is available.

III. UTILIZING ONBOARD HYDROGRAPHIC PROCESSING SOFTWARE

For Hydrographic data gathering, the traditional approach is to send a platform on a data gathering mission and raw data will be stored internally on a hard drive ready for analysis until it can be accessed by the operator upon recovery.

The method proposed in this paper uses a software developed by CARIS called 'Onboard'. This software takes the file that has been written by the hydrographic hardware system and processes the data in accordance with a pre-defined workflow. This workflow is determined by the hydrographer in accordance with the requirements of the hydrographic instruction or mission plan before the survey commences. As part of this workflow the processing steps can be defined, and the product to be output can be determined for transmission to a control center.



CARIS Onboard Process Flow Diagram

In the case of CARIS Onboard, the individual processes are based on the proven technology of existing hydrographic processing software that has been in use for over 20 years, using the CARIS HIPS software code base. The workflow would typically be conversion to native format, calculation of uncertainty values, application of sensor and environmental data and the production of a raster surface with various attributes (depth, uncertainty, intensity etc.).

IV. SCALABILITY OF DATA PRODUCTS

A key principal to this method is the ability to define the type and size of the data product that is to be output. This is critical as it will reflect the nature of the survey mission and what bandwidth (if any) is available to pass processed datasets, images of those datasets or metadata to the controlling surveyor.

In all cases, the processed data will retain its integrity, with both the sonar files and the CARIS format files being stored on the platform's internal memory. This allows the surveyor to investigate areas of interest in more detail and ensure that no sensor data is lost.

To fully exploit the benefits of real time processing, the data can be sent to the control center or operator of the platform. The nature of this data is dependent on the communications bandwidth of the platform, it is evident that a surface vessel with radio communications is able to transmit a great deal more data than a subsea vehicle relying on acoustic means. To meet this requirement the CARIS Onboard software can be configured to output data products ranging from a few kilobytes to the full dataset. Some examples of the data products available are Geo-referenced imagery of the bathymetry, Sidescan Mosaics, Bathymetric Contours, ASCII depths or a QC report on the data quality.

Although these processes are currently focused on hydrographic data, additional sources of information gathered from oceanographic sensors can be added into a product for storage or transmission in near real time along with the bathymetric surface. This proves to be especially useful for multi sensor acquisition in areas with an unknown bathymetry, and for projects where the bathymetric features have a direct influence on the oceanographic processes to be observed.

V. ADVANTAGES OF THE ONBOARD APPROACH

There are numerous advantages to the method described, notably:

(a) Data volumes. Large amounts of data can be processed and condensed into meaningful information in a short space of time. Automating this process also reduces manpower requirements which may be critical on vessels with limited space.
(b) Command & Control. The onboard processing of the data and subsequent transmission allows a central command platform to control several units that may be manned or unmanned, and re-task as required based on the data acquired in near real-time.
(c) Critical factor determination in near real time. The bathymetric data that can be sent in near real time allows the hydrographer to determine mission critical information. An example of this may be an unmanned platform operating ahead of a vessel that is forwarding minimum depth information in order to determine navigable routes.
(d) Mission failure prevention. The surveyor can determine if the platform is gathering data as required during the survey rather than waiting for recovery. This is especially beneficial with autonomous platforms, where traditionally the quality of the data gathered could only be determined after recovery and post-processing.
(e) Data integrity is maintained. As detailed above, the original data files are maintained and any soundings converted into CARIS format are not deleted, so investigation into areas of interest can be carried out upon recovery of the survey platform.
(f) Data quality can be transmitted as a data product. This can be sent in addition to any bathymetric data to allow quantitative assessment of the data, and may be represented to the chart user as an additional layer (for example, Additional Military Layer (AML)).
(g) The CARIS Onboard software is part of a traditional recognized workflow for hydrographic chart production using well-established CARIS software, which reduces the time taken to go from Ping-to-Chart. Indeed there is also scope for further integration with cartographic tools

VI. LIMITATIONS TO THIS APPROACH

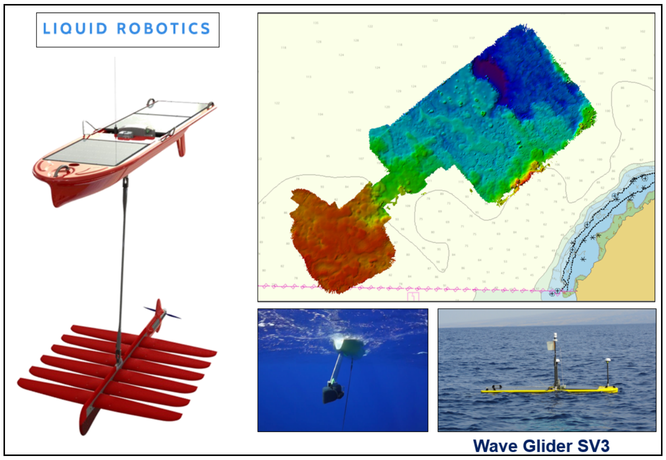
As the process described here is automated, there are still some processes that cannot be included in the hydrographic workflow. With current technology, the following may be required to be applied after recovery of the platform and dataset:

(a) Sound Velocity (SV) Correction. Currently, SV sensors involve a physical deployment of a probe into the water. Although this process has been partially automated by some manufacturers, it has not been fully solved for autonomous vessels at the time of writing.
(b) Post Processed Positioning. As the name suggests, improved position data would need to be applied after it has been calculated, typically after the survey.
(c) Tide Corrections. This may be mitigated by radio links to tide gauges, however more complex cotidal regimes may require this data to be applied post-survey.

VII. PROOF OF CONCEPT

In order to evaluate the use of onboard processing software for real-world applications, several trials were conducted on various platforms. These ranged from fully autonomous long duration surface platforms such as the Liquid Robotics Wave Glider SV3 to manned survey launches such as NOAA's Bay

Hydro II. In each trial the software was shown as a minimum to provide significant time benefits to the surveyor as part of the hydrographic survey process. In addition, each of the advantages listed above were seen, depending on the nature of the platform and type of mission.



An example of real-world trials – autonomous surveying with the Liquid Robotics Wave Glider SV3 showing the data product transmitted from the survey platform

VIII. CONCLUSION

The use of the near real-time data processing methods outlined in this paper have many significant benefits in support of hydrographic surveying and the acquisition of large oceanographic datasets. As platforms increasingly become more and more autonomous, with greater data volumes, automated processing of data will become a necessity. Software such as CARIS Onboard would be an integral part of a toolset to be used by the hydrographic surveyor to meet these requirements in hydrographic survey operations.

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BIOGRAPHIES

Michael Redmayne has a MSC and IHO/FIG Cat. A in Hydrographic Science (2008) from the University of Southern Mississippi, USA. He has been a Hydrographer since 2003 after joining the Hydrographic service of the Royal Navy (retired 2010), and currently handles accounts for CARIS USA.