Hydro INTERNATIONAL

THE GLOBAL MAGAZINE FOR HYDROGRAPHY
WWW.HYDRO-INTERNATIONAL.COM
geomares
VOLUME 26 | ISSUE 1 | 2022

Accelerating Subsea Data Processing using Artificial Intelligence

Automatic Detection of Seafloor Pipelines with Deep Learning

How to Choose the Right Hydrographic Processing Software

Key Considerations Before Investing

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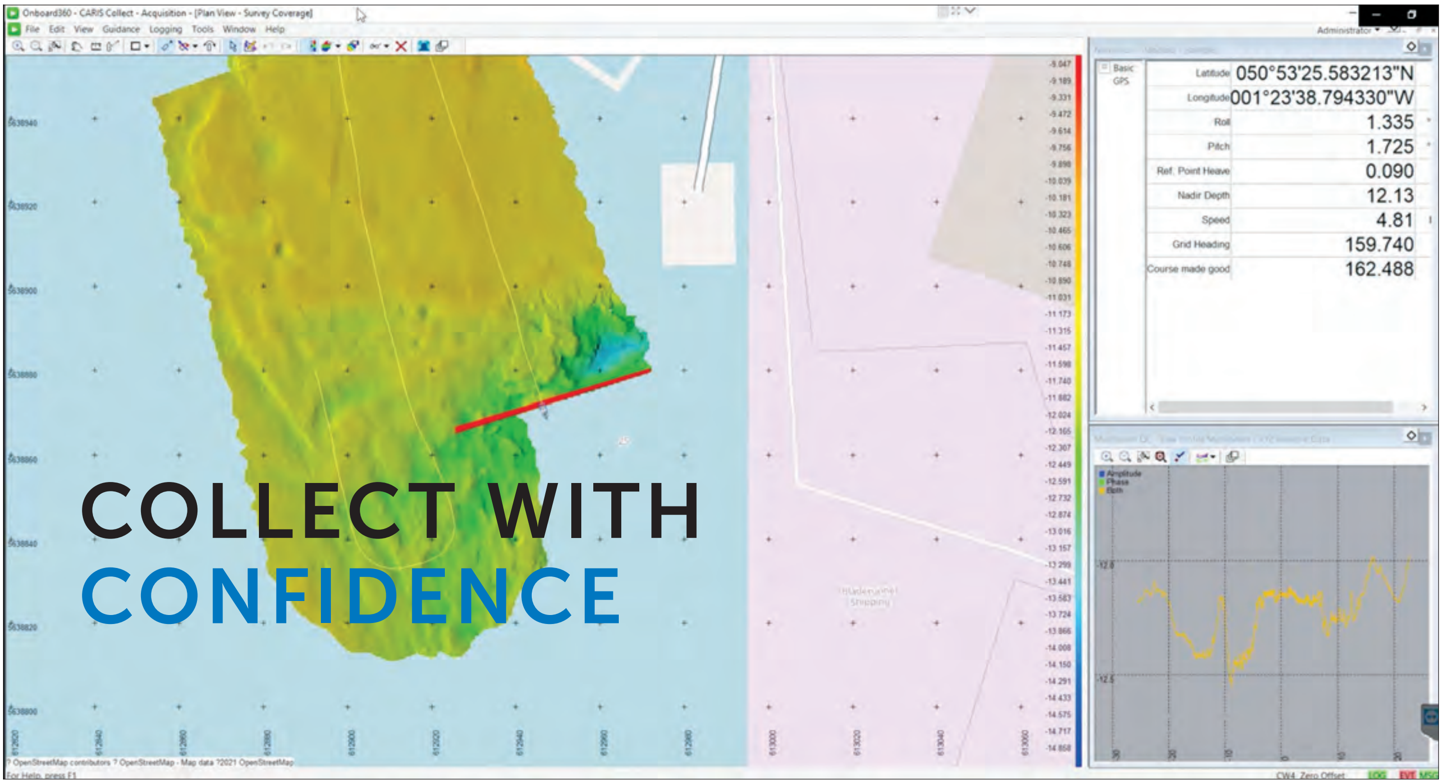

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Cover Story

The image on this edition's front cover shows the Geosurveyor X, a GEOxyz offshore support vessel. The vessel is used – amongst other tasks – to survey offshore wind farm sites. It has a length of 20.56 metres and a beam of 7.5 metres and can accommodate 12 passengers and 3 crew. Geosurveyor X has a maximum speed of 25 knots. (Courtesy: GEOxyz)

Speeding up the green energy transition

In 1972, *The Limits to Growth* saw the light of the day, a report published by the Club of Rome. The message: to keep the Earth liveable, we must control economic growth. To think that this was half a century ago! If anything stands out today, it's that we didn't do anything with that warning; we simply persisted in the same old way. Meanwhile, however, the Earth's atmosphere is warming as we burn more and more fossil fuels that are still available in huge amounts; amounts that turned out to be much larger than those assumed by the Club of Rome.

Twenty years after the publication that caused so much commotion, Dennis L. Meadows, Donella H. Meadows and Jørgen Randers, three of the report's authors, wrote a book that can safely be described as its successor. The alarm bells resonate in the title: *Beyond the Limits*. However, the book didn't cause nearly as much of a stir as its predecessor. While things were in many ways worse than 20 years earlier, the world was in a good mood in the early 1990s; the Cold War was over and the economic boom was gently blossoming, and criticism of the downsides to unprecedented growth was not a story that the world was eager for.

A few years earlier, in 1988, the Intergovernmental Panel on Climate Change (IPCC) was established. Its first overview report was published in 1990. The scientists wrote that they were pretty sure that human activity was significantly increasing the concentration of greenhouse gases, leading to rising temperatures. The exact consequences of this were still uncertain, but the message was loud and clear: Planet Earth is likely to face a lot of trouble if no action is taken.

Since then, international meetings have been held on climate change for more than 30 years. Over the same period, annual greenhouse gas emissions have increased by 50%. One could wonder if there is any point to those climate summits; it's almost impossible not to be sceptical. To be fair, significant steps have been taken over the past years, but the inconvenient truth is that noble words have been followed by scant action.

"The Glasgow Climate Pact: A disturbing outcome and some bright spots", was the headline of Kees Vendrik's, chief economist of the Triodos Bank – a Dutch bank from the ethical banking movement – analysis of COP26, the climate summit in Glasgow, Scotland. "The world did not fulfil its moral obligation to put together an ambitious plan to prevent catastrophic climate change," he stated.

Sometimes, a single event appears to be the sudden burst of acceleration that causes a revolution. Such an event may well be the brutal invasion of the Putin regime in Ukraine. Of course, one of the pitfalls of writing an editorial is dwelling on current events, but things could begin to move very fast, as the dependency of many Western countries on Russian gas and oil is suddenly felt as a heavy burden. Relying on energy resources from Russia means in practice that many European countries are being held hostage by a corrupt administration that makes a mockery of international treaties.

Making headway in ending the energy system's dependency on Russian gas will inevitably catapult the transition towards renewable sources such as wind and solar. It is therefore a case of one man's loss being another man's gain. For the hydrographic industry, this means the possibility of even more projects on the horizon.

Every year, *Hydro International* conducts an industry survey among hydrographic professionals. This year's edition revealed a number of striking trend shifts, with offshore wind as the key growth market. The Russian invasion of Ukraine will accelerate the energy transition, resulting in many more survey activities, in particular for offshore wind farms. This, in turn, will lead to an even greater need for hydrographic surveyors. There are therefore many challenges ahead for our sector! Half a century after the Club of Rome released its alarming report, the move towards a sustainable world is finally being set in motion. Endless studies, surveys and reports from experts, round table meetings and conferences may be less effective than a reckless irresponsible act of disproportionate aggression that shook the foundations of the world community, we could – a bit short-sightedly, perhaps – cynically conclude. Let's see how well this editorial will age.

▲ *Wim van Wegen*

Wim van Wegen, head of content, Hydro International
✉ **info@hydrografie.info**

Ocean Infinity Expands Robotic Fleet with Six Additional AUVs

▲ *This latest order from Ocean Infinity takes their fleet of HUGIN AUVs to more than 20.*

Kongsberg Maritime has announced that Ocean Infinity has signed an order for six HUGIN Autonomous Underwater Vehicles (AUVs) rated to 3,000 metres depth. The vehicles are equipped with a geophysical sensor suite and the latest-generation Kongsberg batteries. The new vehicles will be mobilized for global operations, enabled by Ocean Infinity's remote operations infrastructure. The vehicles will integrate as part of the Armada fleet of uncrewed and optionally-crewed vessels and will augment the company's existing AUVs, rated to 6,000 metres depth.

Dan Hook, CTO of Ocean Infinity, said: "Lessening the environmental impact of operations at sea is core to our business, and with an expanded fleet of robotics we'll have greater capacity to offer sustainable offshore data acquisition services. Using these AUVs as part of our robotic fleet, we'll be supporting the growing renewables sector with remote data and inspection services."

NOAA Unveils 2022 Hydrographic Survey Season Plans

NOAA hydrographic survey ships and contractors are preparing for the 2022 hydrographic survey season in U.S. coastal waters and beyond. The ships collect bathymetric data (i.e. map the seafloor) to support nautical charting, modelling and research, but also collect other environmental data to support a variety of ecosystem sciences.

NOAA considers hydrographic survey requests from stakeholders such as marine pilots, local port authorities, the U.S. Coast Guard and the boating community, and also considers other hydrographic and NOAA science priorities in determining where to survey and when. It is worth visiting NOAA's 'living' story map to find out more about the mapping projects and whether a hydrographic vessel will be in your area this year.

MSM Ocean and Sonardyne Join Forces on Tsunami Early Warning System

▲ *MSM Ocean and Sonardyne have agreed to partner on tsunami early warning systems. (Courtesy: MSM Ocean)*

Metocean and environmental data measurement specialist MSM Ocean and marine technology company Sonardyne have agreed to team up on the supply of a complete solution for warning coastal communities of a tsunami. The two companies can now jointly provide at-risk coastal nations with a single source of supply of tsunami early warning systems.

The agreement combines MSM Ocean's expertise in oceanographic measurement buoys, onboard data processing and telecommunications with Sonardyne's highly precise deepwater pressure measurement and acoustic through-water telemetry capabilities. Together, these allow minute changes in deepwater pressure at the seafloor that indicate a tsunami to be reliably detected, triggering a direct alert to national emergency organizations via acoustic and satellite communications, all within seconds. The tsunami early warning system is fully International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) compliant and can be deployed in areas of up to 7,000m water depth.

iXblue Delivers SAS Dedicated to Ifremer's New 6,000m-rated AUV

Ifremer, the French research institute for ocean science, has received its new synthetic aperture sonar (SAS) from iXblue. It will equip the institute's new 6,000m-rated autonomous underwater vehicle (AUV) dedicated to deep-sea exploration. This SAS, the Sams-150, offers a unique seabed mapping solution perfectly suited to deep-sea autonomous vehicles. Benefiting from more than 20 years of development within iXblue, this technology is already being operated by world-class navies and scientific institutes. This interferometric SAS allows for simultaneous real-time imaging and high-resolution bathymetric mapping of the seabed.

"With a swath width of 500m for a constant resolution of 6cm, our new Sams-150 sonar optimizes the compromise between the resolution and range of imaging solutions. Thanks to its interferometric processing, a high-resolution bathymetric model can be generated simultaneously with the production of the imaging data, thus ensuring a coverage equivalent to more than ten times the height of water under the sensor," explains Bertrand Chemisky, head of civil activities at iXblue Sonar division. "Our SAS technology, coupled with an inertial navigation system and an acoustic positioning system, will ensure precise georeferencing of each pixel, thus enabling the creation of homogeneous maps over large areas."

▲ *The UlyX AUV being deployed during its first dives.*

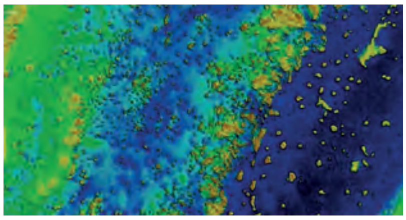
Sea Mobility and Scour Assessment for New Offshore Wind Farm in the Irish Sea

▲ *Combined with the Gwynt y Môr, Awel y Môr will form one of Europe's largest offshore wind farms. (Image courtesy: RWE)*

RWE Renewables has appointed ABPmer to support the design of the Awel y Môr Offshore Wind Farm in the Irish Sea. The marine consultancy company is assessing the sediment mobility and scour potential at the wind farm site, located in a dynamic area off the north Wales coast. The work will be used to help support export cable route selection, as well as inform the ongoing wind turbine foundation and array/export cable design process.

To map the behavioural characteristics of the seabed across the wind farm site and export cable corridor, ABPmer will analyse oceanographic data from its SEASTATES metocean database, recent and historic seabed surveys, and geophysical data specifically collected for the project. High-resolution hydrodynamic and sediment transport modelling are also being used to map the detail of long-term regional scale sediment transport pathways.

EOMAP Awarded New Survey Contract by UKHO



▲ *Very-high-resolution SDB imagery by EOMAP, Lighthouse Reef, Belize. (Courtesy: Maxar)*

The UK Hydrographic Office (UKHO) has signed a new three-to-five-year framework contract for satellite-derived bathymetry (SDB) with EOMAP. In the course of a competitive tender, the German-based experts for earth observation have – again – been ranked first-choice provider of SDB. The first batch covers 9,000 square kilometres of shallow waters off the coast of Belize. Starting in 2022, EOMAP will deliver high-resolution shallow-water grids from SDB technology to UKHO, with the first survey covering the waters of Belize. This survey will be the first complete survey of some of these waters, including where uncharted coral pinnacles are currently noted on the chart.

"The UKHO is pleased to continue its partnership with EOMAP, leveraging cutting-edge survey technology such as SDB to supplement existing hydrographic surveying and related charting products. SDB adds significant value and cost-effectiveness when surveying difficult-to-access areas of the ocean, while minimizing the impact on the marine environment," said Ian Davies, international hydrographic portfolio manager, UKHO.

Woolpert Acquires Vessel-based Hydrographic Survey Firm

▲ *eTrac, the vessel-based hydrographic survey firm acquired by Woolpert, is headquartered in California.*

Woolpert has acquired eTrac, a vessel-based hydrographic survey and marine technology firm that conducts custom and integrated marine services for projects across the U.S. and its territories.

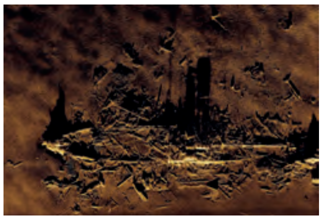
These marine services include collecting and processing hydrographic survey and bathymetric mapping data for coastal mapping, navigation safety and nautical charting, high-resolution multibeam sonar data for shipping channel dredging and pipeline inspections, underwater imagery and aerial Lidar data for change analysis, and vessel positioning and monitoring.

Woolpert vice president and maritime solutions market director John Gerhard said this merger combines the hydrographic survey and multibeam sonar expertise of eTrac with Woolpert's aerial topographic, bathymetric and geospatial capabilities to deepen service offerings, leverage inherent synergies, achieve operational efficiencies and extend geographic reach. It also unites eTrac's fleet of survey vessels with Woolpert's 49 manned and unmanned aircraft.

Like Woolpert, eTrac was founded as an engineering and survey company. While Woolpert grew to develop integrated architecture, engineering and geospatial (AEG) capabilities, eTrac carved out its niche in vessel-based hydrographic services. Both have retained that fundamental, problem-solving perspective. This has led the firms to not only deliver geospatial services but to develop products where needed solutions did not yet exist.

ThayerMahan Joins Forces with UNH/NOAA Partnership

ThayerMahan, a world leader in autonomous maritime solutions, has established a collaborative partnership with the Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC).



▲ *A shipwreck offshore of Virginia/North Carolina captured at high speed by the SeaScout system.*

CCOM/JHC is a formal cooperative partnership between the University of New Hampshire (UNH) and the NOAA and was founded in 1999. CCOM, a complementary university centre in the UNH School of Marine Science and Ocean Engineering, expands the scope of ocean mapping interaction and collaboration with the private sector, other government agencies and other universities.

The partnership developed after the two organizations worked together at sea. Representatives from ThayerMahan and CCOM/UNH deployed a SeaScout system on the NOAA ship *Okeanos Explorer* during the EX-19-04 2019 technology demonstration. During the expedition, synthetic aperture sonar (SAS) data was collected over a series of underwater cultural heritage locations off the U.S. Northeast and Mid-Atlantic coasts. ThayerMahan provided local command and control of the SeaScout system from the ship and demonstrated remote command and control from their operations centre in Groton, Connecticut.

Trained for Different Scenarios

Automatic Detection of Seafloor Pipelines with Deep Learning

Seafloor pipelines are a critical infrastructure for oil and gas transport. Timely inspection is required to verify their integrity and determine the need for maintenance, as failures in these pipes may interrupt the vital distribution of oil and gas and cause environmental damage. The inspection of seafloor pipelines is a challenging task, however, due to their remote location and vast length. Autonomous underwater vehicles (AUVs) such as HUGIN (Figure 1), equipped with algorithms for pipeline detection and following, represent cost-effective innovations in these operations.

AUTONOMOUS PIPELINE INSPECTION

Traditionally, external pipeline inspection has been conducted with large and advanced offshore vessels applying towed or remotely operated vehicles (ROVs). The objective is to detect burial, exposure, free spans and buckling of the pipeline, as well as indications of damage due to third party activities, such as trawling and anchoring, and debris near the pipeline. During the last two decades, AUVs have emerged as a more efficient and less costly solution, as they are stable platforms that can travel faster (typically 3-5 knots compared to 1-2 knots for inspection ROVs) and operate without constant supervision from a mothership. Typical payload sensors for these AUVs include multibeam echo sounders (MBES), sidescan sonar and optical cameras.

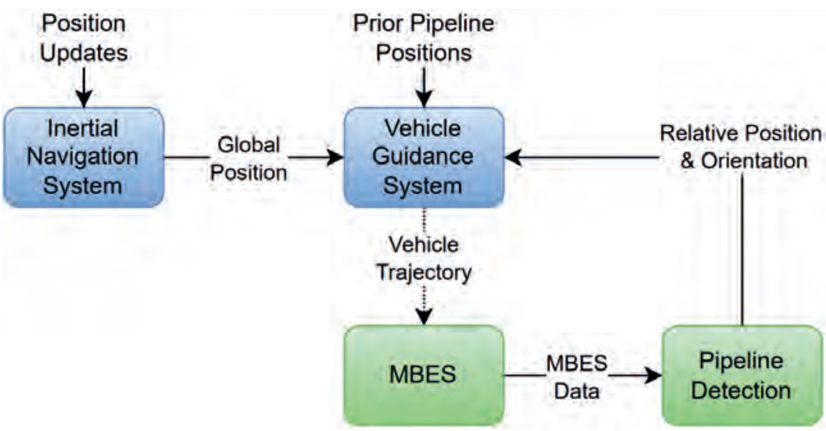
To collect high-quality sensor data for inspection, the AUV must follow the pipeline at a specified cross-distance and height. Global position estimates from the vehicle's inertial navigation system will not suffice, due to inevitable drift in the estimates over time and uncertainties in prior pipeline position data. One solution is the automatic detection of pipelines in the sensor data to provide real-time input to the vehicle's control system, which then maintains the desired relative position and orientation (see flow chart in Figure 2). This is the basis for the PipeTracker system [1], cooperatively developed and refined since 2010 by the Norwegian Defence Research Establishment (FFI) and Kongsberg Maritime (KM). The PipeTracker applies traditional image analysis techniques to detect and track pipelines in sensor data from either sidescan sonar or MBES.

SENSOR DATA

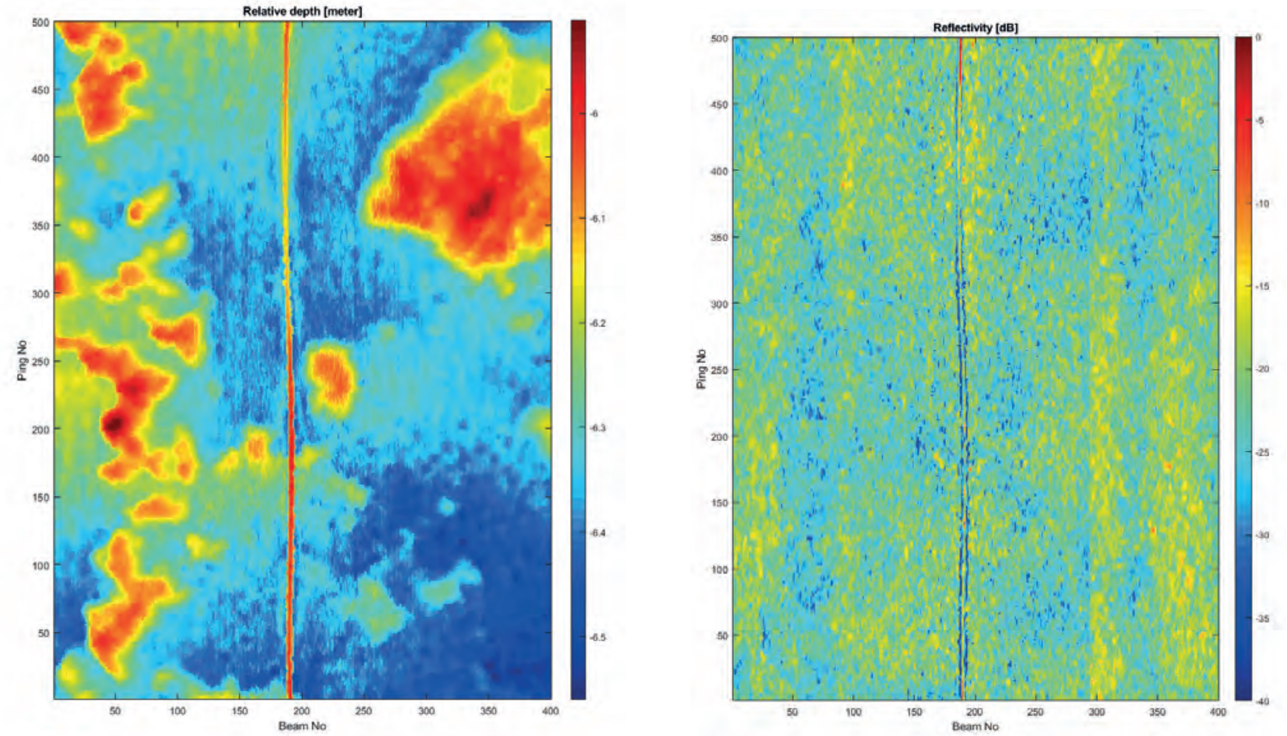
An MBES is an active sonar for bathymetric mapping of a swath centred below the AUV. The sensor estimates both the strength and time delay of the seafloor backscatter, providing the reflectivity and relative depth values. Figure 3 presents a pipeline data example collected with a HUGIN AUV in shallow water off the coast of Brazil, while Figure 4 presents a TileCam camera image of a corresponding subarea.

Through a collaboration between FFI, the University of Oslo and KM, we investigated how to use deep learning, described further in the

▲ *Figure 1: A HUGIN AUV preparing to dive.*



▲ *Figure 2: Flow chart of pipeline detection and following. The AUV uses both prior knowledge of the pipeline position and real-time sensor data analysis to maintain the specified sensing geometry. The green boxes provide the scope of our work, while the blue boxes give the larger navigation context.*



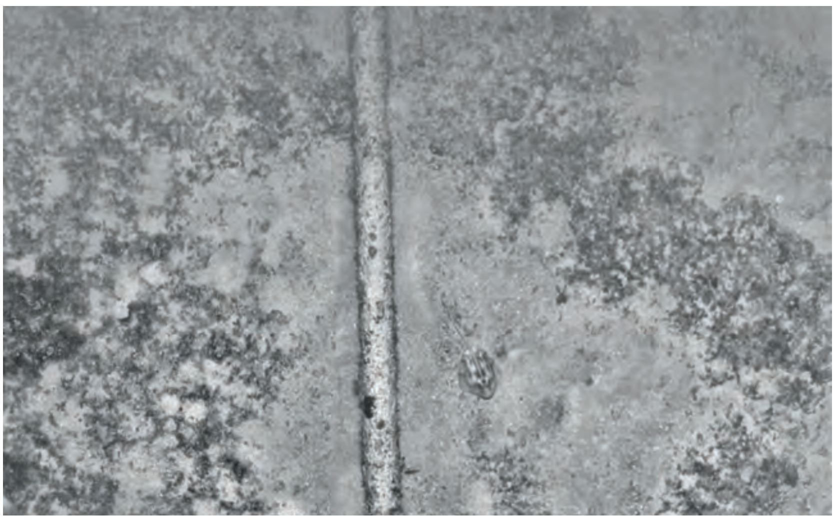
▲ *Figure 3: Depth and reflectivity data from the EM2040 MBES mounted on a HUGIN AUV. A single pipeline (inner diameter 15cm) is visible in both data channels at approximately beam number 200. Image sizes are 22m x 61m.*

next section, for the automatic online detection of seafloor pipelines in MBES data. To this end, we created and defined a method for annotating (labelling) pipelines in MBES data. Moreover, we tailored and extended existing state-of-the-art deep learning-based object detection techniques to this novel task and imaging format.

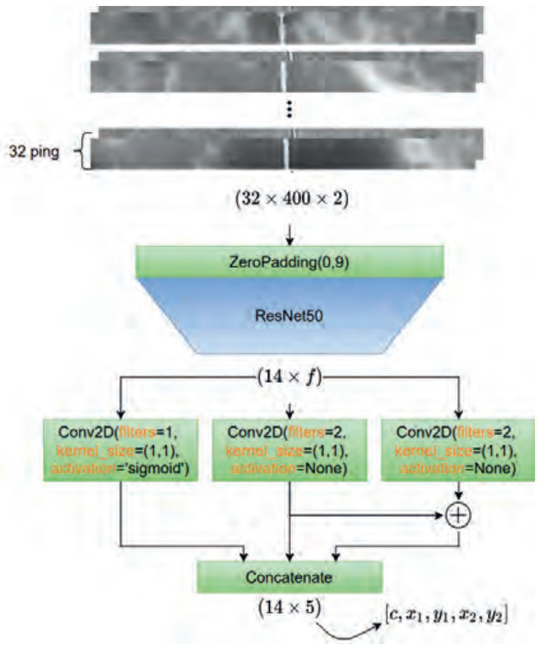
The dataset used is a collection of MBES images from 15 pipeline inspection missions gathered with different HUGIN AUVs by KM and FFI at various locations around the world.

DEEP LEARNING FOR PIPELINE DETECTION

Deep learning refers to artificial neural network



▲ *Figure 4: A HUGIN camera image of the pipeline. The image covers a seafloor area of approximately 6m x 4m centred at ping number 200.*



▲ *Figure 5: Illustration of the pipeline detection model. At the top, MBES image segments are input to the model. At the bottom, five variables represent the detection results, where c indicates whether the input contains a pipeline or not and x1,x2,x3,x4 gives the coordinates of the pipeline segment if the input contains a pipeline. The blue box is an established deep learning architecture, while the green boxes customize the model to the MBES data format and seafloor pipeline detection task.*

Empowering autonomous survey.

Able to conduct both remote-controlled and supervised autonomous operations the DriX USV offers outstanding seakeeping and speed capabilities. It is a versatile and efficient USV that can host a wide range of payloads and that offers optimum conditions for high quality data acquisition in both shallow and deep waters.

(ANN) models with many layers. Larger models coupled with increasing computational capabilities and huge amounts of data have led to the success of ANNs. In recent years, ANNs combined with deep learning has become the best performing method for countless data processing tasks, such as image classification, detection, tracking, speech recognition, synthesis, translation, the games Chess and Go, and many more.

With the impressive achievements of deep learning, we sought to tailor and test it on the pipeline detection task. To make the best use of deep learning, we looked to state-of-the-art methods on similar tasks. In particular, we looked to models that could detect and classify different objects in optical images. Processing and interpreting optical images are two of the early beneficiaries of deep learning, and have also spearheaded much of its progress. We then tailored the model, a combination of ResNet50 [2] and You Only Look Once (YOLO) [3], to the idiosyncrasies of the seafloor pipeline detection task and the MBES data format. Figure 5 illustrates our deep learning model.

Deep learning has two stages, training and inference. The training phase shows the model millions of examples of what we want it to do, and through this training phase, the model becomes increasingly better. After training, the model is expected to understand the general principle of the task and to work well on new unseen, similar examples. When the model is used to interpret new examples after the training phase, it is in inference mode. The performance in the inference mode is the measure of success of the model.

One key factor for a successful deep learning model is the data examples it trains on. To this end, we need to define and create labels that can supervise the model to learn its task. As existing deep learning models such as ResNet and YOLO do not support our data format and task, we created a tool to manually annotate pipelines in MBES data. These annotations defined the goal of the task, which is to automatically predict whether an MBES image segment contains seafloor pipelines or not, and where the detected pipelines are. In addition to data and labels, training an ANN requires formulating the task objective mathematically. Because of the peculiarities of the task and data format, we also proposed a novel seafloor pipeline detection task objective, the details of which are described in [4].

RESULTS

We evaluated the trained model in two ways: (i) how well it predicted whether an MBES image segment contained a pipeline, and (ii) how precisely it located the top of pipelines. During testing, our model correctly predicted pipelines in over 85% of previously unseen cases; in other words, data examples that the model had not trained on. Moreover, the model also correctly located the pipelines with on average less than two pixels offset to the labelled pipeline top, where pixels are pings and beams, interchangeably. For reference, the width of the pipeline in the depth channel of Figure 5 spans approximately five beams.

CONCLUSION AND PROSPECTS

This work demonstrates that deep learning can effectively be used to detect pipelines in MBES data. Although traditional image analysis algorithms are already successfully used to detect seafloor pipelines, these are generally hand-designed and, to some degree, bespoke for the application. With deep learning, however, the model learns through training how to detect the pipelines in different scenarios. A deep learning model can often be improved simply by using more data examples. This means that detection performance can be improved over time as less common pipe configurations and environments are encountered – without the need for new algorithm development or refinement.

In further work, we will consider applying deep learning to detect seafloor pipelines in both sidescan sonar and optical images. Moreover, we envision using deep learning to evaluate the state of the pipeline in all the different sensor data, which would automate the inspection even further. ◂

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Vemund Sigmundson Schøyen wrote his Master's thesis for the University of Oslo (UiO) in collaboration with the Norwegian Defence Research Establishment (FFI) in 2019/20. Schøyen is currently pursuing a PhD in biologically inspired artificial intelligence at the Centre for Integrative Neuroplasticity at UiO.

Per Espen Hagen has worked with AUV-related research and development for nearly 30 years. He was a member of the HUGIN AUV development team at the FFI from the early 1990s; from 1999 as project manager. In 2008, Hagen joined Kongsberg Maritime, where he is currently product manager in the Marine Robotics department.

Øivind Midtgaard received an MSc in theoretical physics from the Norwegian University of Technology and Science, Trondheim, in 1990. From 1991 to 1996, he developed non-destructive testing technology for the offshore oil and gas industry. He has worked in the Underwater Robotics group at the FFI since 1996.

Narada Warakagoda is a principal scientist at FFI. He previously worked at Telenor R&D and SINTEF, contributing mainly to speech recognition and the Internet of Things. Warakagoda joined FFI in 2016, where he works in the field of marine robotics with an emphasis on image analysis and machine learning.

Key Considerations Before Investing

How to Choose the Right Hydrographic Processing Software

When looking to buy hydrographic processing software, it is important to establish the requirements in order to find the best software for the job at hand. The users' technical skills, the type of data required and the intended operations on the data will differ depending on the project. This article provides an overview of the most important aspects of hydrographic processing software that a buyer should take into consideration before investing in a solution.

OPERATIONS AND APPLICATIONS

The core of any hydrographic processing software is the actual processing operations and potential limitations. Some software provides the user more freedom by allowing code imports, while other software is more specialized towards specific hydrography-related ends. A distinction can be made between the initial cleaning and validating of a dataset (smoothening and despiking) and further operations that are more specific per project.

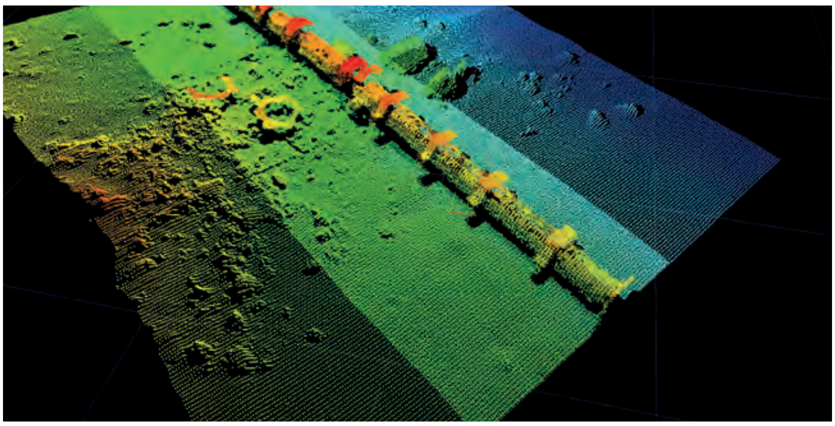
When it comes to hydrographic data, certain factors play a role that are not relevant for other types of geospatial data, such as:

- Sound velocity correction
- Multibeam calibration methods
- Multibeam backscatter processing functionality
- Multibeam water column imaging support
- Tidal reduction

Hydrographic processing software may be able to take these factors into account, providing automatic corrections. If the software will be used with unfiltered sonar data, the capability to clean the sounding data is a must-have and available in all hydrographic software. Additionally, surveying projects will require an in-depth analysis of the quality of a survey. Hydrographic software can provide this in different ways, with varying parameters on which the user can base the assessment of accuracy.

Geodetic support functionalities help the user with coordinate systems, datums and ellipsoidal references which can be crucial for large datasets. General operations for things like slope, aspect, contour and volume computations can be useful to have at hand in the software for analytical purposes, but are not always available. The type of interpolation methods and digital terrain model (DTM) transformations available is important for any geospatial data project. A margin of error is present with any interpolation, and the type of interpolation determines the error that will be present in the final model.

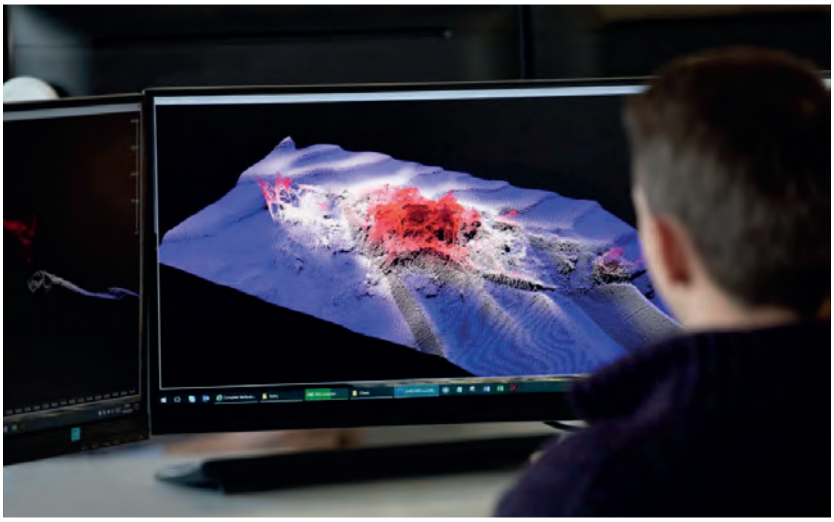
The processing of data to perform such operations and transformations is not equally important for every type of project, user or type of work, so a buyer should consider what the software will be used for, and by whom. For example, highly technical users who are able to code custom algorithms may require the ability for code imports, while less technically skilled users will require more functionalities to be directly available.



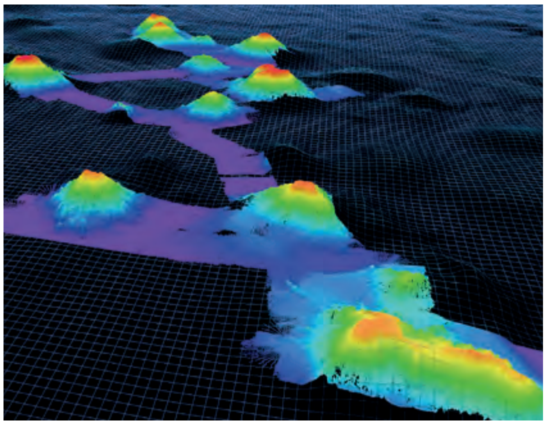
In more specialized cases like pipeline surveying, specific software has been created to process the bathymetric data obtained. (Courtesy: DOFSubsea)

SPECIALIZED SOFTWARE VS FLEXIBILITY

Software for processing hydrographic data is often capable of processing other types of geospatial data as well. Depending on the processing needs, buyers should decide whether specialized software for hydrographic data is desired, or more flexible software that is capable of processing various types of geospatial data. Again, software that allows for code imports is more flexible for other types of data and applications but requires a higher level of technical ability from its users. Hydrographic surveys can have many different objectives, and different challenges will occur during the processing of the resulting data. In more specialized cases like pipeline surveying, specific software has been created to process the bathymetric data obtained. Naturally, it is always important to choose the right tool for the job, and the same goes for software. Time,



▲*Software developers such as Teledyne CARIS often offer comprehensive remote training sessions for their hydrographic data processing solutions. (Courtesy: Teledyne CARIS)*



▲ *New bathymetry data of the New England Seamounts. (Courtesy: NOAA Ocean Exploration)*

money, and resources can be saved by choosing the right software, especially for specialized cases.

INPUT/OUTPUT

There are numerous types of file formats in which hydrographic data can be delivered, ranging from point clouds in standard XYZ formats to brand-own formats. When choosing software, it is important to be aware of not only the types of formats the software can import, but also which formats can be written as output so that the workflow can be continued in other software or by other parties. Most software will have a maximum input file size which can be hardware-dependent or limited by the software itself.

SYSTEM REQUIREMENTS

Geospatial data processing operations can be quite intensive for the average computer, especially when working with 3D visualizations. Always check the software's system requirements, such as the required RAM and processor specs, to make sure that the existing hardware does not limit the performance of the software.

EQUIPMENT-BASED SOFTWARE

Besides software with standard file input that will often use point cloud input files (obtained using Lidar or single-beam sonar, for instance), there are also software packages that use data acquired with specific instruments (often of the same brand). Since this software is designed to deal with the data provided by certain equipment (e.g. a specific sensor), it is likely to be more efficient and effective for that data than other software.

USER INTERFACE

The software's user interface should be easy to work with in order to avoid the user wasting valuable time due to not being able to easily find the required functionalities. While this is largely dependent on the technical level of the end-user and also a matter of personal taste, it is nevertheless an important factor to take into consideration when investing in the processing software. If the main user base of the software will be of a lower technical level, the interface will play a larger role than it would for users with a high level of technical expertise.

VISUALIZATION

Just as workflows have different types of input data, there are also differences in the types of visualization required. When the output of a workflow contains a strong visual aspect, the buyer should make this a priority. The buyer should take note of whether there are 2D or 3D visualization possibilities as well as 'fly-through' options. These allow the user to check the terrain by passing through it with point-of-view (POV) vision and possibly subsequently export this as a video file. Scientific-based workflows will often rely less on visualization as these require less visual and subjective analysis of results.

SUPPORT

One of the most important factors to consider when buying any software is the available support. This can range from an online Q&A section to online tutorials and courses. Larger software companies offer courses and training, while all the required documentation and information is often available online for free for many commonly used software packages. However, this can depend on the popularity and price of the software, so it is important to check the available customer support and documentation beforehand, along with the associated costs.

UPDATES AND RELEASE NOTES

All software contains bugs. What is important is that bugs are fixed promptly and software improvements are made and communicated to users. Clear release notes on software bug fixes and improvements help the users to stay up to date on the latest developments.

CONCLUSION

The right hydrographic processing software for a job depends on a wide range of factors. Before investing in a solution, buyers should therefore reflect on the intended operations and applications for the data, the types of inputs and outputs (including the system requirements), the user interface and the users' level of technical ability, the need for visualization in relation to the type of project, and what kind of support is available to users. These considerations will help to optimize the return on investment in hydrographic processing software. ◀

About the author

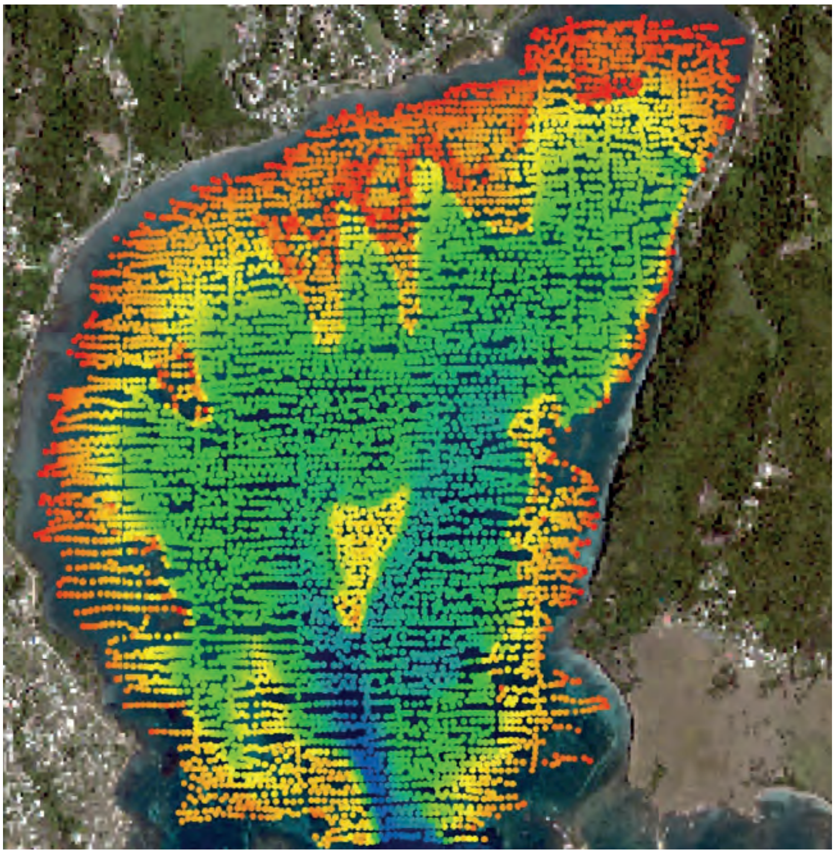
Lars Langhorst is currently developing software to predict sedimentation levels in the Panama Canal using machine learning, with which he will conclude his MSc in Geomatics. He is always learning and working to keep abreast of the latest developments in geomatics, hydrography and AI, and contributes to this knowledge through articles.

in Lars Langhorst

Towards Time Efficiencies, Cost savings and Improved Safety

Satellite-derived Bathymetry for Surveying Jamaica's Coastal Waters

Central America and the Caribbean region are blessed with beautiful coastal waters. However, most nations, if not all, face the arduous task of developing and managing their natural resources, such as the marine environment, while focusing on economic development. Under the International Convention for the Safety of Life at Sea (SOLAS), Jamaica is responsible for executing hydrographic surveys of its coastal waters. The National Land Agency (NLA), the recognized national hydrographic office, has a hydrographic survey programme in place to cover the bathymetry of Jamaica's coastal waters in fulfilment of its responsibility to collect, maintain and disseminate nautical information to all its stakeholders. Through a contractual arrangement, Jamaica's admiralty charts are produced and maintained by the United Kingdom Hydrographic Office (UKHO). The acquisition of refined, reliable and enhanced hydrographic information in Jamaica's territorial waters supports Jamaica's development as a nation, tapping further into the blue economy.

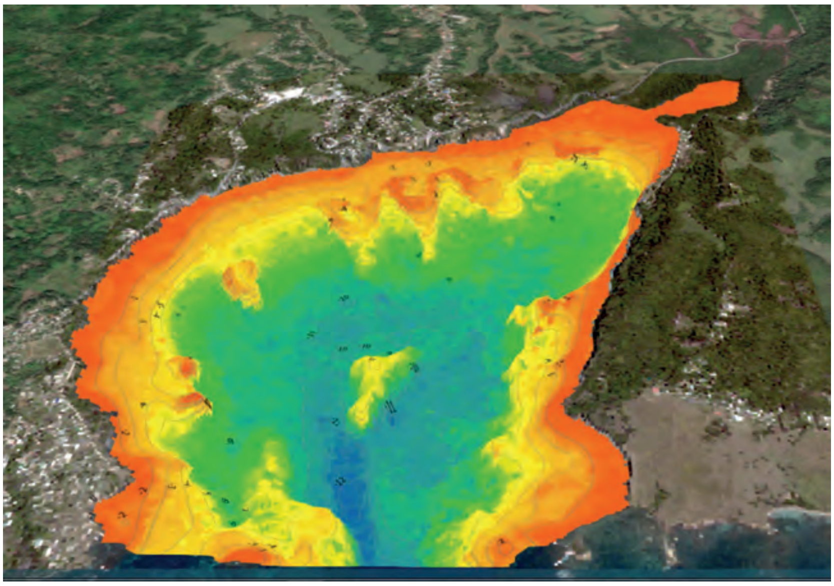


▲ *Figure 1: NLA single beam echosounder survey data in Bowden Harbour showing survey track lines.*

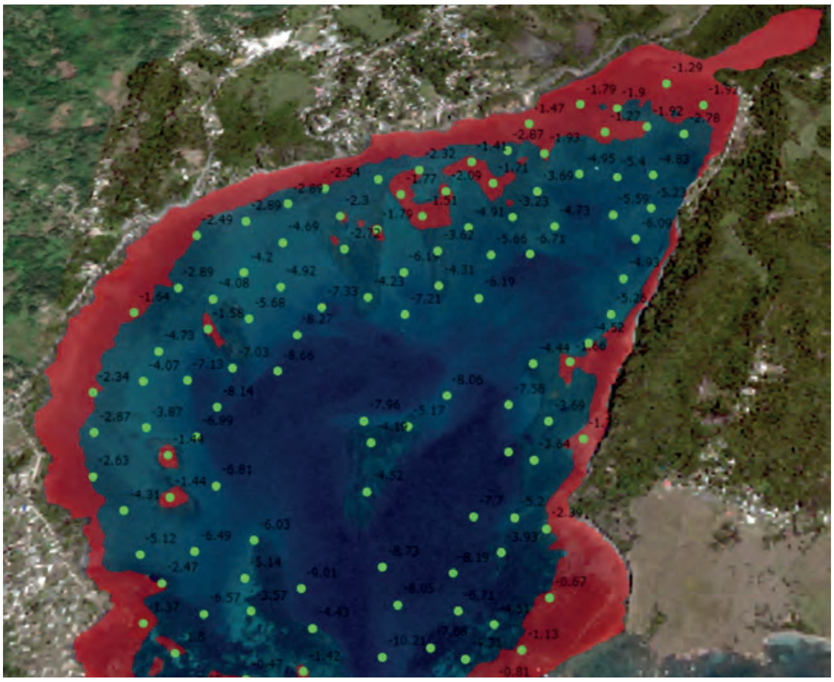
BACKGROUND TO THE NATIONAL LAND AGENCY (NLA)

Under the Surveys and Mapping Division (SMD), the NLA is responsible for carrying out hydrographic surveys of Jamaica's harbours and territorial waters. The NLA is the national hydrographic office recognized by the International Hydrographic Organization (IHO). While operating under resource constraints, as with most small island developing states, the SMD is tasked with surveying its coastal waters. Nonetheless, an intergovernmental agency partnership has been brokered through the National Hydrographic Committee (NHC), resulting in an agreement for the use of a

▲ *Figure 2: Survey crew, from left to right: AB P. Anderson, Orean Hinds, OS A. Thomas, Richard Mais, Brian Scott, OS J. East, Diego Billings and CPO R. Chambers.*



▲ *Figure 3: SDB integrated with single beam data to produce a surface.*



▲ *Figure 4: Depth points and depth contours. No-go areas are in red and shoal points in green.*

Jamaica Defence Force Coast Guard vessel, which was utilized in the recent survey of Bowden Harbour in St. Thomas.

PORT MORANT (BOWDEN) HARBOUR SINGLE BEAM SONAR BATHYMETRIC SURVEY

The NLA conducted a single beam hydrographic survey of Port Morant (Bowden) Harbour in December 2020. The purpose of the survey was to collect hydrographic data of the harbour to aid the update of Admiralty Chart number 275-3 and fulfil other hydrographic needs. The survey covered an area of approximately 3.4 square kilometres (340 hectares). The line spacing for the development lines was 20m, which ran perpendicular to the depth contours. Approximately 171 development lines (planned lines) and 43 check lines were generated for the survey area. The survey was carried out over ten days, collecting sonar data from 06:00 to 18:00.

A considerable amount of human and capital resources are required for the execution of a successful traditional single beam sonar survey (SBSS) or multibeam sonar survey (MBSS). As can be seen in Figure 2, eight people were involved in the data collection for this project. The Jamaica Defence Force Coast Guard provided four boat crew coxswain and boat aids, while the NLA provided four people as part of the data acquisition team.

COLLABORATION: NATIONAL LAND AGENCY AND TCARTA CARIBE

The Bowden Harbour Project presented an excellent opportunity as a case study into the usefulness of satellite-derived bathymetry (SDB) to improve the efficiency of hydrographic surveys, as the SDB data was readily available through TCarta. Additionally, the team wanted to test the potential for SDB to support single beam surveys. TCarta Caribe provided the NLA with the SDB of Bowden Harbour to carry out the investigation.

TCarta and the NLA also teamed up after the survey for a capacity-building workshop, presented by TCarta, to address three objectives: (1) the SDB's potential to inform hydrographic survey planning; (2) to describe/explain SDB production methods; and (3) to perform data analysis and comparisons between a single beam derived surface and that of the SDB for Bowden Harbour.

TCarta's team advised that, as the SDB software is integrated into ESRI in ArcGIS Pro, and as the NLA already uses ArcGIS Pro, it would be a natural progression for NLA to build its marine spatial data infrastructure within this platform.

The workshop continued with a session on the process of producing SDB using TCarta proprietary software, the Multispectral Bathymetry Tool (MBT) in ArcGIS Pro. In addition, the workshop focused on the process involved in the production of SDB in Bowden Harbour and gave an overview of SDB's feasibility in Jamaica's coastal waters. The final session zeroed in on the statistical analysis of SDB in comparison to NLA single beam data.

TCarta used three NLA transect lines, as ground 'truthing', for the correction of the SDB data, from which a surface was produced (see Figure 3).

A graphic representation of the SDB-derived data is shown in Figure 4, highlighting the usefulness of planning survey lines and mapping areas of caution.

Difference category (metres)	Number of points in category	Percentage
-4	10	1.15%
-3	58	6.66%
-2	131	15.04%
-1	213	24.45%
-0.5	99	11.37%
0.5	35	4.02%
1	121	13.89%
2	157	18.03%
3	45	5.17%
4	2	0.23%

▲*Table 1: Point-to-point comparison of TCARTA SDB vs. NLA SBES.*

TCARTA SDB VS NLA SBES

The NLA's GIS unit created a difference map of the single beam echosounder (SBES) data versus the TCarta SDB data. Preceding the creation of the difference map, TCarta applied a datum adjustment to the SDB, adjusting the SDB depths to the local mean low water (MLW) datum, approximately 0.25m above lowest astronomical tide (LAT). A point-to-point comparison was carried out by the NLA's team using ArcGIS, analysing 871 congruent points. The results show that 15.39% of the points had a difference of ±0.5m, while 86.80% had a difference within ±2 metres (see Table 1).

With the generation of the difference map, an analysis could be made of the general agreement between the data, cross-referencing these differences with the seafloor topology and identifying possible trends at various depth ranges (see Figure 5). The differences between the NLA SBES data and the TCarta SDB data are shown as spot heights. Positive (+) differences (58.67%) indicate that the SDB data is deeper and negative (–) differences (41.33%) indicate that the SDB data is shallower than the NLA SBES data.

NLA also analysed ten particular areas with varying seafloor topology. The general trend indicates that SDB data tends to be shallower in deeper water and deeper in shallow water, compared to NLA's SBES data.

DISCUSSION

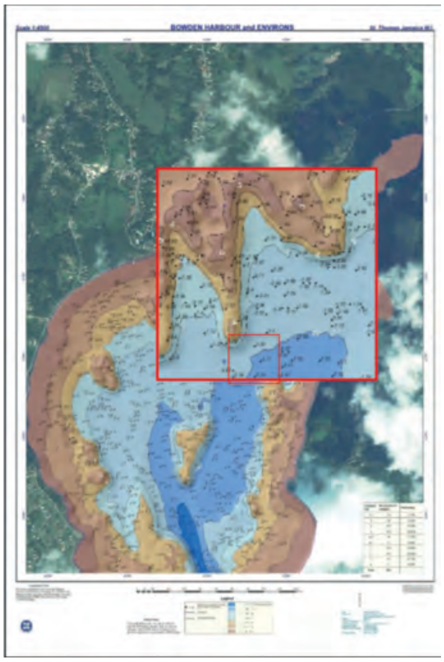
The SDB technology was found to give a general indication of the depths within the project area. SDB gradually detects changes in depths; in other words, it 'smoothe' the changes in depth and will not detect sudden outcrops or rocks. As such, SDB is a useful tool for filling in the gaps. These could be gaps between survey lines with respect to SBES or gaps in depths to the zero-depth contour, which are hard to survey with typical survey vessels, therefore improving on the spatial resolution. SDB is an excellent tool for planning and conducting feasibility studies of traditional bathymetric surveys to be undertaken, especially where inadequate chart data exists.

SDB technology can be a catalyst for the mapping of Jamaica's coastal waters, which is vital to the blue economy and to further aid our understanding of climate change and other environmental impacts. With the current focus of the region on the Seabed 2030 initiative, which aims to survey the ocean floor by the year 2030, there is a high demand for bathymetric data in the region. The current pandemic has seen already limited resources being diverted to the health sector, and those resources that are allocated to the marine environment must be used as efficiently as possible. Some countries have also seen the limited mobilization of hydrographic survey teams, to reduce costs as well as to reduce the spread of COVID-19. Collaborative approaches, such as the integration of SDB with traditional survey methods, is one approach that can aid the realization of the Seabed 2030 initiative.

The integration of satellite-based hydrography, which promotes time efficiencies, cost savings and improved safety, lends itself to the development of the NLA's hydrographic programme. This collaboration and integration of technologies goes hand in hand with the NLA's commitment to research and development.

CONCLUSION

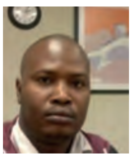
SDB is a quick and inexpensive way to obtain a general idea of depths for applications such as fisheries and post-disaster response and rescue planning. It can be used as a tool for planning and conducting feasibility studies of traditional bathymetric surveys, but the vessel should navigate with the utmost care where the underkeel clearance is calculated to be less than five metres. ◀



▲ *Figure 5: Comparison between the SBES and SDB-derived data; positive values indicate that SDB data is deeper and negative values indicate that SDB data is shallower than the SBES data.*

About the authors

Carol Fisher is programme manager/lead hydrographer at TCarta Caribe, Kingston, Jamaica.
Born and raised in Jamaica, Carol Fisher holds a degree in land surveying/GIS and is a certified hydrographer with over 19 years of extensive experience working on hydrographic programmes in Jamaica.



Antonio Williams took on the role of chief hydrographer for Jamaica in 2011. He is an IHO Cat. A certified hydrographer who is passionate about hydrography for safety of navigation and is an enabler of the sustainable development of the blue economy in the Caribbean.

Deep-sea Robotics Development and Space Technology Cooperation

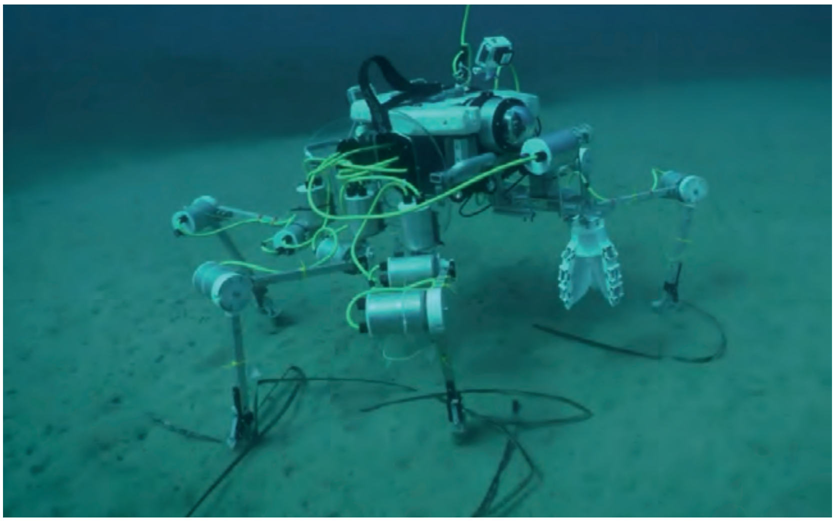
The Synergies of Exploring Deep-sea Ecosystems and Icy Moons

During the past years, terrestrial and extraterrestrial ocean research have increasingly joined forces to merge expertise and technical solutions in the exploration of marine systems on Earth and in space. This includes solutions for robotic applications, autonomy and sensor integration, as well as data analysis. These synergies in biomimetic design, platform artificial intelligence (AI) and life-tracing sensor packages will be applied to the monitoring and surveillance of environmentally delicate habitats on Earth such as cold-water coral reefs or fishing grounds, as well as decommissioning sites. Thus, marine scientific and industrial offshore infrastructures may provide innovative test-bed services for robotics and sensor development.

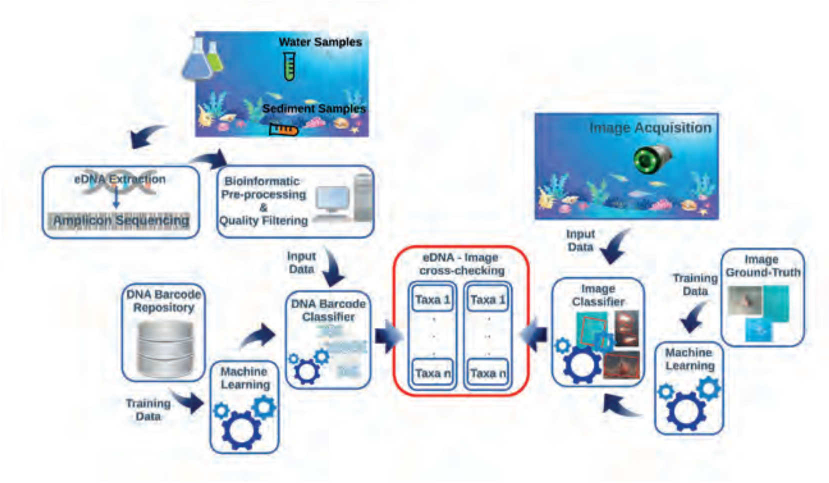
DEEP-SEA ROBOTICS AND ICY MOONS

Marine and space ocean research largely focus on satellite- and buoy-based monitoring. However, recent advances in robotic design, autonomy and sensor integration are creating solutions for the exploration of deep-sea pelagic and benthic environments that are transferable to the vast extraterrestrial oceans of the icy moons Enceladus and Europa. Those water bodies are similar to terrestrial marine systems in terms of pressure, gravity and geothermal-dependent activity, internal tidal bulges and constant darkness, and also share the presence of hydrothermal vent activity (as revealed by Galileo, Cassini-Huygens and Hubble Space Telescope space missions). Fractures on icy surfaces are the product of large geysers emitted as cryovolcanism; in other words, high pressures and strong geothermal gradients produce large fluxes of hot water to be transported to the surface through cracks and crevasses in the ice cap. Due to decompression shocks, water suddenly evaporates and freezes once it emerges into space, falling back to the surface as snow.

The exploration of life on icy moons is regarded as a result of the propitious momentum introduced by space agencies, but a contribution will also be made by the latest developments in deep-sea robotics, which in turn may benefit from space research solutions. For example, sensor packages based on optoacoustics, passive acoustics and omics (eDNA) that are currently used for deep-sea ecosystems research may represent off-the-shelf solutions for the bioprospecting of exo-oceans' putative life at ranges of sizes of bacteria and beyond. Given the geological timeframe of exo-oceans' existence and venting activity (which is comparable to that of Earth), a bold thought would be to consider that extraterrestrial organisms could even be present within the megafauna size ranges, and even with some level of morphological analogy (i.e. species of different phylogenetic origin are similar since they have responded to shared selective pressures). Extraterrestrial fauna may resemble sessile or motile morphological



▲ *Figure 1: The bioinspired underwater legged robot SILVER2 during field trials in Savona, Italy. Thanks to its springy legs, SILVER2 is capable of agile locomotion on several types of sediment and exhibits low environmental disturbance in terms of acoustic footprint and impact on the sediment. Here, SILVER2 is equipped with a soft robotic gripper to enable the collection of delicate objects of arbitrary shape. (Courtesy: Igor d'India)*



▲ *Figure 2: Main steps of the pipeline for eDNA and imaging data integration. The eDNA is collected from the water or sediment and processed through metabarcoding protocols. This step includes several bioinformatics preprocessing actions before going through an automated DNA barcode classifier pipeline. The images acquired on cameras contextually to eDNA sampling are post-processed through an image classifier routine. Both protocols need independent reference repositories to train the machine learning classifiers before the cross-checking of the taxonomic assignments derived from eDNA and images. (Image from Stefanni et al., 2022)*

designs of our marine organisms within major marine phyla, such as Porifera (sponges), Arthropoda (e.g. crustaceans), Mollusca (e.g. octopus), Cnidaria (corals and jellyfishes), Anellida (worms) and even Chordata (e.g. fishes).

In this scenario, marine research is currently establishing growing high-tech benthopelagic networks of cabled and uncabled observatories and their docked mobile multiparametric platforms (i.e. AUVs and ROV, as well as crawlers, rovers and biomimetic robots) for reasons varying from astrophysics to neutrino detection (i.e. the neutrino telescopes of KM3NeT) and ecological, oceanographic and geochemical monitoring (e.g. Ocean network Canada-ONC, European Multidisciplinary Seafloor and water column Observatory (EMSO) and Ocean Observatories Intitiative-OOI). Marine platforms have increased their autonomy capacity in recent years to match their space counterparts, but their increasingly biomimetic design may make it possible to study complex deep-sea and exo-oceans environments using the highly integrated life-tracing, oceanographic and geochemical sensor packages described above.

Exo-ocean exploration implies a technological challenge of much higher complexity than the exploration of any deep-sea location. Platform and sensor payloads are likely to constrain their use for exo-ocean exploration for the coming decades, and the penetration of large ice caps will require robotic carrier solutions (e.g. cryobots) bearing a tool to carve tunnels kilometres long. Here, the future development of deep-sea robotics is presented in relation to the engagement of space technologies in three major research areas: biomimetic structural and energetic design, AI, and miniaturization of life-tracing sensor technologies.

BIOMIMETIC STRUCTURAL AND ENERGETIC DESIGN

The exploration of extreme environments such as terrestrial abyssal areas and exo-oceans requires innovative platforms that employ locomotion modalities beyond those of traditional assets (e.g. AUVs, crawlers and rovers). It also requires energy provision for longer mission autonomies and upgrades in cooperative behaviour (i.e. groups of units, to maximize the effectiveness of missions).

The development of biomimetic legged platforms that employ agile arthropod-like locomotion could dramatically enhance mobility on irregular terrains such as hydrothermal vent fields, and allow these platforms to anchor to the substrate and even sense using their limbs. The adaptation to dynamically changing, rough terrains and high pressure can also be achieved with new soft and lighter materials with a density close to seawater.

Another major challenge related to robotic autonomy is energy provision, which presently focuses on the development of efficient but often large batteries or hydrogen source equivalents such as hydrogen peroxide (H_2O_2) fuel cells. However, organisms rely on the creation of energy through biological processes, and this can be replicated by an artificial metabolism for a renewable in situ energy provision, such as via the processing of substrata (feeding-like functions), which may also be of potential benefit to space exploration. This could be based on a new generation of energetically autopoietic microbial fuel cells, but these represent a threat to space missions according to the contamination protocols of the Committee on Space Research (COSPAR). In the near future, the bacterial components may be removed and biochemical reaction routes inferred with reverse engineering approaches based on AI.

PLATFORM AI IN MISSION AUTONOMY AND DATA PROCESSING

The traditional command cycle for autonomous robotic marine platforms involves human operators sending fixed commands to the vehicle and the vehicle executing those commands and transmitting the acquired data to a ship or shore. However, this is increasingly unfeasible as such platforms work at increasing ocean depths, and is impossible in exo-ocean scenarios. AI and long-term autonomy are therefore required for key functionalities of long-term missions in operational contexts where data transmission is constrained (e.g. large oceanic depths, shielding ice sheets and astronomical bodies, and over immense distances). Such AI upgrades are required for navigation and trajectory planning, adaptive sampling and sensing, as well as the processing and summarization of very large amounts of heterogeneous data in real time. Hardware architectures capable of controlling sensors and executing algorithms in real time for content-based data interpretation independently from remote computational resources are the core of the edge computing paradigm.

For example, terrain relative navigation and simultaneous localization and mapping (SLAM) methods can be used to assist in navigation when acoustic ultra-short baseline (USBL) and single beacon signals are not available for localization. These have the benefit of being independent from any external infrastructure, but the limitation that local coordinates must ultimately be referenced back to a global frame. Deep-sea operational test beds will be critical in the development and refinement of robust navigation solutions for use in exo-oceans.

Furthermore, as marine robotic platforms acquire a huge amount of heterogeneous data, a relevant effort is being dedicated to autonomous data processing. AI applications must not only be capable of detecting and extracting useful information to reduce memory storage and to ease communication activities, but they also need to autonomously explain why such information is relevant and how it has been extracted from the data. Autonomous on-board interpretation of data and recommand of the vehicle, as in the case of adaptive sampling/sensing, have been developed in contexts where no a priori scientific knowledge of environmental features is available. In such cases, methods for the adaptive online exploration of target features of interest will be required to autonomously evidence new observations, based on a history of previous ones.

LIFE-TRACING SENSOR PACKAGES

In astrobiology, the effort in the integration of sensor payload is currently centred on micro-organisms, with conceived prototypes integrating molecular analyses with the micro-imaging and spectral analysis of liquid samples. A deep-sea-inspired technological development may contribute to shifting the focus of astrobiology research from microcellular to multicellular and larger-sized organisms.

While marine research is developing omics sensors to trace environmental DNA/RNA (eDNA/eRNA), the exo-ocean community is developing direct and indirect methods of detection of environmental nucleoside alternative structures, such as xeno-nucleic acids (eXNA). This is paving the way for the creation of in situ omics sensors that can scout for signatures of life in extreme environments (e.g. hydrothermal vents). This life-tracing capability in the deep sea will increasingly

▲ *Figure 3: The deep-sea crawler MANSIO-VIATOR is capable of performing autonomous monitoring missions on the sea floor. It consists of an autonomous crawler and its garage.*

combine image and molecular sensor technologies into highly integrated payloads (Figure 2). Such a development will converge with the in situ microfluidic sampling capability in the near future. Microfluidic sensors are true molecular laboratories. Presently, in situ microfluidic sampling capabilities are far from being achieved in the marine medium, but they are relevant for the identification of life within ice shells and exo-oceans on icy moons. Such sensors are assembled for the detection of molecules (e.g. amino acids), biopolymers (e.g. lipids as universal markers of life and carbohydrates as proxies for photosynthetic activity) or nucleic acids, using protocols integrated with magnetic particles and the single-channel structure nanopore for sequencing.

CONCLUSIONS: TOWARD A NEW CLASS OF BLUE SERVICES

In the decade of the restoration of the ocean ecosystems, environmental exploration and monitoring technologies are increasingly taking centre stage. By combining marine technologies with space robotics exploration solutions for the monitoring and surveillance of environmentally delicate habitats (e.g. cold-water coral reefs) or at oil and gas platform decommissioning sites, a new framework for dialogue emerges for robots and sensors within three major research topics of interest to produce a new class of blue services. For example, offshore industries could strongly benefit from robotic developments for the surveillance and maintenance of their infrastructures. At the same time, marine scientific and industrial offshore infrastructures may provide innovative test-bed services for robotics and sensor development.

ACKNOWLEDGEMENTS

This research was made possible with the help of the following colleagues: Simone Marini (CNR-ISMAR, Italy), Laurenz Thomsen (Jacobs University, Germany), Jan Albiez (Kraken Robotics, Canada), Peter Weiss (Spartan Space, France), Marcello Calisti (University of Lincoln, UK), Luca Mirimin (Galway Mayo Institute of Technology, Ireland), Fabrizio Vecchi (SZN), Cecilia Laschi (National University of Singapore), Andrew Branch (Jet Propulsion Laboratory, USA), Evan B. Clark (Jet Propulsion Laboratory, USA), Mar Fleixas (Jet Propulsion Laboratory, USA), Bernard Foing (ILEWG EuroMoonMars, Leiden University, The Netherlands) Armin Wedler (Institut für Robotik und Mechatronik, Germany), Damianos Chatzievangelou (ICM-CSIC), Michael Tangherlini (SZN), Autun Purser (Alfred Wegener Institute, Germany), Roberto Danovaro (SZN, Polytechnic University of Marche), Lewis Dartnell (University of Leicester, UK), Ivan Masmitja (ICM-CSIC), Claudio Lo Iacono (ICM-CSIC). ◀

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About the authors

Jacopo Aguzzi's research focuses on the presence and behaviour of marine species and changes in sampled biodiversity at different temporal scales, making use of new robotic monitoring technologies. Cabled observatories, crawlers, ROVs, AUVs and neutrino telescope imaging are used to gather intensive spatio-temporal data to describe animal movements and interactions in the oceanic water column and seabed scenarios.

Giacomo Picardi is a robotic engineer specialized in bioinspired design and control. His research focuses on abstracting locomotion and manipulation principles observed in marine animals and embodying them in robotic platforms to enable or simplify monitoring and intervention tasks in the field.

Sergio Stefanni's research interests are molecular ecology, population genetics and the phylogeny of marine organisms. He is keen to apply molecular tools to study marine biodiversity to contribute to technological developments in sampling and processing data as well as the development of bioinspired vehicles for research at sea.

Sascha Flögel's research interests are focused on cold-water coral ecosystems and their controlling long-term parameters. In order to acquire long-term data series of physical and biogeochemical data, he uses a variety of fixed ocean observatories (landers and moorings), as well as autonomous robotic solutions such as crawlers. In addition, he develops and uses innovative assets such as submarine fuel cells to increase long-term monitoring capabilities.

Detecting Shipwrecks in Waters All Around the World

Wreck search is a special application of hydrographic surveying. Countless sunken ships – or what's left of them – have been discovered over the years, often by means of a combined survey with multibeam and sidescan sonar. AUVs and ROVs are also used for underwater survey missions, such as detecting and mapping submerged wrecks. We have selected a series of articles that immerse you in the world of discovering shipwrecks in seas across the globe.

SEARCH FOR THE RAVENEL WRECK IN SAINT-PIERRE-ET-MIQUELON

A research campaign that aims to find the wreck of the *Ravenel* fishing trawler, which disappeared in January 1962 off the coast of Saint-Pierre-et-Miquelon (France), began on 23 May 2021. Despite several attempts over the past decades, the wreck remains unfound. Thanks to the use of the DriX Unmanned Surface Vessel (USV), designed, developed and operated by iXblue, this new research campaign will use unprecedented technological capacity to solve the mystery surrounding one of the most important shipwrecks in the history of French fishing.

Resurvey imagery of the wreck of La Surveillante by the RV Keary as part of the 2020 INFOMAR Programme. (Courtesy: INFOMAR).

MAPPING AND MONITORING THE WRECK OF LA SURVEILLANTE

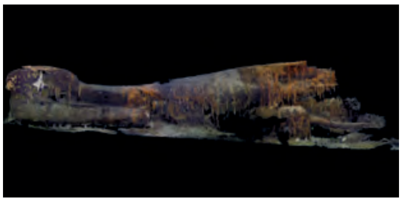
Ongoing collaboration between INFOMAR and the National Monuments Service continues to produce exciting results on Ireland's underwater cultural heritage. Last autumn, the Geological Survey Ireland's RV *Keary* resurveyed the 1797 wreck of the French frigate *La Surveillante* in the course of its 2020 INFOMAR operations along the south-west coast.

AUTOMATIC SHIPWRECK DETECTION IN BATHYMETRY DATA

Archaeologists have long been interested in shipwrecks. These sites can tell us about ancient transportation and trading routes, technological innovations and cultural exchanges over thousands of years. Documenting shipwrecks can be a difficult task, however. With breakthroughs in remote sensing technology (specifically sonar and radar), researchers have been able to acquire highly resolved maps of ocean floors. Consequently, we can also locate cultural objects – like shipwrecks – sitting on the bottom of oceans, lakes and other bodies of water.

HOW ROBOTIC TECHNOLOGY OFFICIALLY IDENTIFIED THE WORLD WAR II SUBMARINE S-28 GRAVESITE

After 75 years, and using advanced imaging technology, ocean explorer Tim Taylor and his Lost 52 Expedition Team have officially discovered the final resting place of the 49 sailors of the U.S. submarine S-28 (SS-133) off Oahu, Hawaii. The U.S. Navy recently validated the identity of the wreck, which Taylor located in 2017. ◂



Remains of the WW II submarine S-28.

From broad brush filtering to pinpoint intelligent data selection

Accelerating Subsea Data Processing using Artificial Intelligence

Artificial intelligence (AI) first came to light in the 1950s, when the ability of a machine to undertake an operation and adapt to changing conditions without human input was skirting the edges of science fiction. The mainstream recognition the topic now enjoys is due partly to having enough computing power to make AI work for us. Artificially smart machines and software are no longer science fiction, and the consequences are everywhere, including in geophysical data processing.

Developments in the hydroacoustic technology sector have made the final mile in the subsea survey value chain closer to a 100-metre sprint. Post-processing is much faster these days, because geophysical data acquired by multibeam echosounders, bathymetric sonars and sub-bottom profilers is cleaner than it ever was. Improvements to transducers, motion sensors and positioning technology combine with improved onboard processing to significantly reduce the time it takes for clients to see the final data.

OPTIMIZING OFFSHORE WIND

Survey costs are always under scrutiny, but massive growth in the offshore wind sector will add more pressure to optimize the entire value chain for speed and efficiency. New wind capacity is coming online regularly, with January's announcement that Germany has approved new wind farms to the measure of 1.9GW just the latest in a long line of new projects.

Offshore wind power must remain competitively priced to realize its potential as a fossil fuel replacement however, and energy companies, their prime contractors and operational partners will continue to seek out the most competitive offering as long as the provider can deliver the standard of data required.

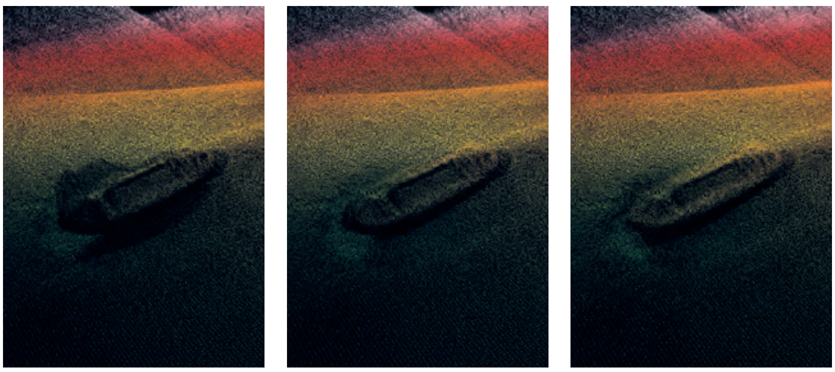
AI and its machine learning counterpart have the potential to further accelerate the entire journey of data from the seabed or below it to the desks of the engineers that depend on it. Reducing the time from commission to delivery can make marine survey services more affordable, thereby providing companies that invest in innovative solutions with a more competitive edge in their respective markets.

AI AND GEOPHYSICAL DATA

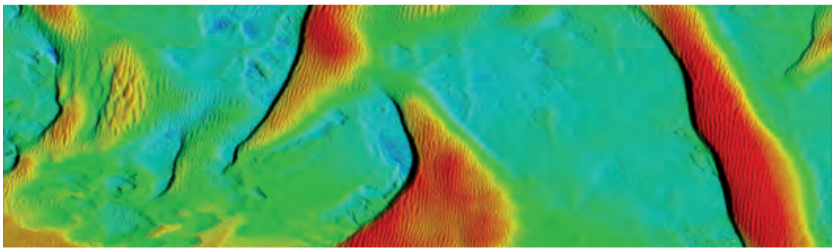
In this context, the application of AI and machine learning to geophysical data will not always be a choice, as survey companies with offshore wind clients must demonstrate a noticeably clear value proposition to remain competitive. Fortunately, new AI technologies are coming through the development pipeline to streamline data handling and processing, leading to tangible cost reduction opportunities. One such technology is being worked on in a partnership between the University of East Anglia and underwater instruments manufacturer GeoAcoustics Ltd. The team is focused on the creation of an AI-powered upgrade to existing automated filtering in the GeoSwath 4 bathymetric sonar software. The project stands out as its aim is to apply machine learning so that the AI can remove surplus and undesired data autonomously; during acquisition, the system is designed to log virtually clean data, without any user intervention in the cleaning process. This is made possible as the AI was developed to analyse and accept or reject outlying soundings. The user only needs to pay attention to data quality and coverage, and during post-survey processing the focus can be purely on georeferencing of the bathymetric data using deterministic calculations. The final, noise-free and high-resolution bathy products will be fully reproducible with minimal human intervention, with the potential for savings achieved to be passed on to the client.

ACCELERATING INTERFEROMETRY

For GeoAcoustics, the project is a means for the lower-cost GeoSwath 4 bathymetric sonar system to stay head-to-head with industry-leading multibeam echosounders GeoSwath provides ultra-high-resolution swath bathymetry



▲ *Figure 1: Images demonstrating the impact of optimized filter settings on data recorded for a sunken barge off Plymouth, UK.*



▲ *Figure 2:* ***Complete hands-off processing of a number of survey lines with the AI system. This data was collected using a 500kHz GeoSwath system in approximately 20m of water and with a survey line spacing of 40m.***

with up to 12 times water depth seabed coverage and a 240° field of view. On these figures alone, the system outperforms even the most expensive shallow water multibeam systems.

The performance is due to the use of interferometry, a methodology that acquires significantly more data than a multibeam echosounder could along the same survey line. It also works as a side-scan sonar, for example enabling highly detailed images of the base of wind turbine monopiles and cables on the seabed alongside the acquired bathymetric data. Currently, a set of manually configured filters is employed to process GeoSwath data. To achieve the best results, an experienced user is required to optimize these parameter settings – particularly when operated in real-time and in varying environmental conditions. The AI instead provides automated real-time filtering at the click of a single button, without the need for further human intervention, providing clean user-independent data.

The AI processing ensures that sonar-dependent IHO-conformant data can be viewed in real time during acquisition, allowing for dynamic line planning to ensure the collected data meets the required IHO spec for the survey. Traditionally, this is performed onshore after data collection and further surveys would be commissioned if the original data was found to not meet the required spec. AI processing during the initial survey can mitigate this risk and in doing so save time and reduce fuel consumption. The latter of course has the extra advantage of boosting the green credentials of the survey provider.

AI IN ACTION

AI techniques can be used for both real-time data processing and post-processing of bathymetric data. The traditional approach to filter data from a GeoSwath system is to set a number of filters to remove unwanted points. These consist of an amplitude filter, a limits filter, an across track filter and an along track filter. If the area being surveyed is relatively consistent then these settings can be applied and the survey undertaken, however in challenging environments these settings may need to be optimized in real time, which requires operator experience.
By setting the filters too tight (narrow band, see left image, Figure 1) around the seabed, any outliers in the water column are removed but there is the potential of chopping off the top of vertical structures on the seabed. If the filters are set too loose, vertical structures are retained but the data is compromised by adding more outliers from the water column. The middle image shows the optimum balance of filters to capture the entire wreck structure while eliminating as many water column outliers as possible; this was achieved by an experienced operator.

The aim of the AI work is to reduce the need for experienced operators and the subjective decisions that they will make. No two operators will generate identical data products based upon the decisions that they apply.

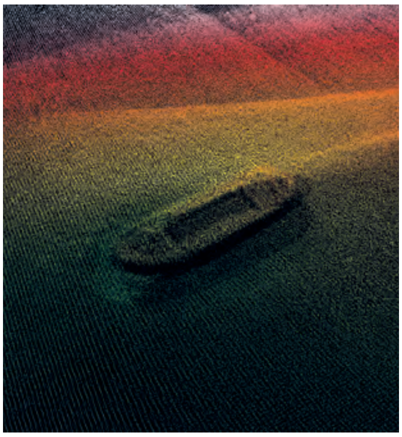
AUGMENTED EFFICIENCY

Through this data, we can see that the AI processing toolset provides comparable results to what an expert operator could achieve in the same time frame (see Figures 2 and 3). Of course, the ability of an AI system to perform so well might be construed as a threat to those professionals whose knowledge, skills and experience are the lifeblood of the marine survey industry.

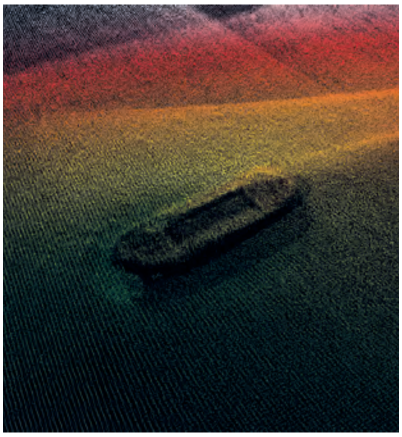
However, AI data processing will not replace marine surveyors; instead, it will help them to do their job even more efficiently, which in the context of changing demands driven by offshore wind energy, will help to secure jobs and benefit the hydrographic survey market as a whole.

GeoSwath users can apply the new AI processing solution through a software upgrade due for release in the latter half of 2022. ◂

Manual cleaning



AI



▲ ***Figure 3: A data specialist spent significant time in post-processing to create the Manual Cleaning image, whereas the AI system delivered its work without additional post-processing filtering while matching the quality achieved by a seasoned professional.***

Danny Websdale is an AI/ML research scientist at GeoAcoustics. He received a BEng degree in computer systems engineering (2014) and a PhD in audio-visual speech processing (2019), both from the University of East Anglia, UK. He is currently working on applying AI for real-time seabed classification.

Francisco J. Gutierrez is product specialist for the GeoSwath 4, Pulsar and TOPAS systems manufactured by GeoAcoustics Ltd. He previously worked as technologist for the Spanish Research Council and as an associate professor of electronics at University of Cadiz, Spain.

Energy Transition: Bright Prospects for Hydrographic Industry

One of the key findings of the recent annual hydrographic industry survey conducted by *Hydro International* is the boom in renewable energy as the indisputable driving force behind a growing need for hydrographic surveyors. To come straight to the point: the energy transition will require a lot more survey activities, in particular for offshore wind farms.

The transition towards a low-emission economy is widely considered as an important growth area for the hydrographic industry. For our survey, we made a distinction between 'traditional' renewables – wind farms – and upcoming renewables, such as tidal and wave energy. 15.7% of the respondents indicated that they regard wind farms as their number one growth area, whereas 10.8% consider tidal and wave energy to be a key opportunity. One survey participant said that the uptake of renewable energy sources offshore should improve prospects for major offshore projects. Many respondents also mentioned how governments across the globe are putting a strong emphasis on investments in the blue economy. One of the respondents noted a downturn in oil and gas exploration, but that this is being replaced by a strong increase in wind farm and cable route surveys.

OFFSHORE OIL AND GAS

With renewables so prominent in the spotlight, we could be tempted to lose sight of the importance of the oil and gas industry to the hydrographic surveying profession. However, they always have had and still have a harmonious relationship, as reflected by the outcome of the question concerning in which domains of hydrography our respondents work; 34.3% indicated that they work in the oil and gas industry. Although the share of fossil energy in the hydrographic sector may decline over the decades to come, it will still be a vital component for the years ahead. One of the comments can be summarized as follows: the survey demand for oil and gas will also increase due to sustainable prices above US$60 per barrel. Another respondent expects an increase in demand for oil and gas as a result of the post-COVID economic recovery.

For the full version of 'Hydrography: Growth Prospects on the Horizon', our report on the key findings of the annual industry survey, please scan the QR code. ◂

▲ *The transition towards a low-emission economy is widely considered as an important growth area for the hydrographic industry. This photo shows the 'Seaway Aimery', an advanced cable installation, repair and maintenance vessel. Seaway 7 has been active in the offshore Renewables Energy industry since 2009, and has since been involved in many projects of the key offshore wind developers in Europe, Taiwan and the US. (Photo courtesy: Seaway 7)*

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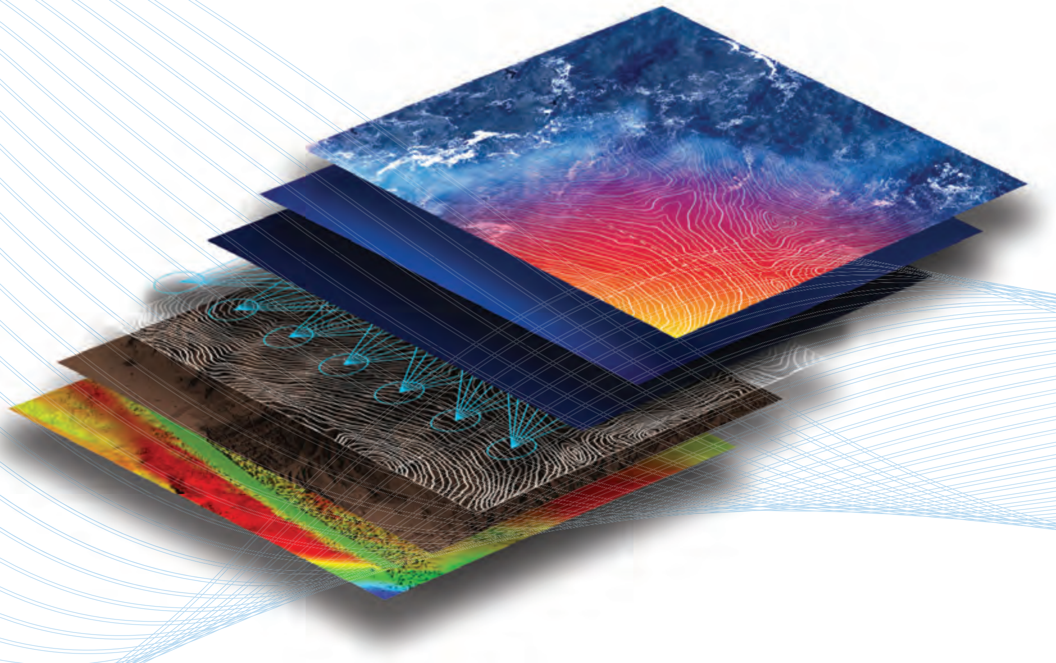

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