Autonomous Solutions to Ship Hull Inspections

Complex Ship Hull Inspections Using Completely Autonomous UUV Solutions

This article explores work currently under way that is helping to meet the complex challenges of ship hull inspections. The following sections describe these challenges and present the solutions that have been devised to meet them. The article provides results obtained in actual real-life experiments conducted by SeeByte and describes future work required to further improve operations.

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TO DATE, GLOBAL NAVIES HAVE relied heavily on teams of expert divers to carry out inspections of the submerged regions of hulls. These divers must contend with very challenging conditions, often facing poor visibility and high levels of risk. It is a time-expensive job and extremely dangerous for divers. This task is, however, being viewed as increasingly important for national security. As a result, developing technology to aid port and harbour protection is becoming an issue of interest and providing an automated solution for ship hull inspection is receiving increased attention.

Smart Unmanned Solutions

Unmanned underwater vehicles (UUVs) are being used to replace the diver for this inspection task. The inherent poor visibility underwater is being overcome by using sonar systems to survey the hull. The final aim of this work is to enable a fully autonomous inspection of the ship hull. To achieve this, the vehicle must be capable of autonomously navigating around a complex, possibly unknown hull structure. The system must be capable of reporting back information of interest (such as possible threats) and so must have reliable and efficient underwater communications. The solution must be capable of inspecting the hull and processing the sensor data in real-time to produce a complete picture of the hull. In short, the vehicle must have a complete situational awareness of its surrounding and have the capability to identify and respond to possible threats. It must also be able to provide guarantees that the entire hull (a 100% coverage rate) has been inspected.

Meeting Challenges

In order to make this possible, challenges that have been addressed include:

- servoing with respect to the hull, including its complex areas
- inspection of the hull using automatic target recognition (ATR) models
- ensuring full coverage through real-time mosaicing.

Servoing with Respect to the Hull

In order to servo the complex regions of the hull (the non-flat hull areas), sonar-driven techniques have been developed. Regular range and bearing estimates to the hull are determined from the sonar data, allowing the vehicle to maintain a constant distance from the hull as it carries out its inspection survey. Correcting the mission trajectory in real-time using information from the sensor allows the vehicle to inspect unknown, unstructured hull regions. The proposed solution uses SeeTrack Offshore, a true dynamic positioning system for remotely operated vehicles (ROVs). The system fuses data from a Doppler velocity log with an accurate heading reference sensor to dead-reckon the system and data from a forward-looking, imaging sonar to identify the hull. It uses that data to control and guide the ROV autonomously around the hull. The distance from the hull and the

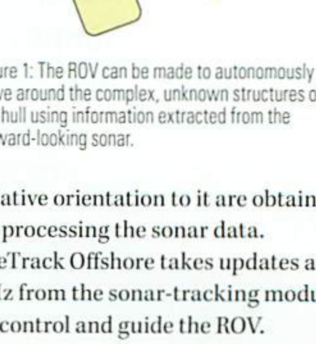

Figure 1: The ROV can be made to autonomously move around the complex, unknown structures of the hull using information extracted from the forward-looking sonar.

relative orientation to it are obtained by processing the sonar data. SeeTrack Offshore takes updates at 5Hz from the sonar-tracking module to control and guide the ROV.
The real challenge arises when facing more complex regions such as

Figure 2: The ROV uses the forward-looking Blueview sonar to determine the range and bearing to the corner of the hull. The information from the sonar is used to autonomously direct the vehicle around the corner. This technology can be used to enable autonomous inspection of the complex regions of the hull.

'Real challenge arises when facing more complex regions such as the corners and running gear'

the corners and running gear. These include the corners around the bow and prow areas. To inspect the corners using a forward-looking sonar, the sonar-tracking module was upgraded so that it could recognise the end of the hull and carefully control the manoeuvring so that the ROV could maintain a safe distance to the hull (see Figure 1). The technique was tested through trials carried out in Scotland around a barge.

The trials carried out at the underwater training centre in Fort William showed that the ROV can be made to manoeuvre around the barge at a constant distance to it. Figure 2 shows the ROV used in this experiment as it was finding its way around the barge.

Figure 3: Automatic target recognition (ATR) results for a sequence of sonar frames containing regions of the hull inspected by the vehicle. Yellow boxes signify possible targets on the hull.

Automatic Target Recognition

The detection of man-made objects on the hull of a ship requires expert sonar operators to carefully observe all of the mission data. To provide an autonomous UUV solution, it is necessary that the vehicle is capable of processing the sonar data in real-time and on board. SeeByte has developed an ATR system that automatically processes the data and highlights possible man-made objects on the hull. The ATR system uses multiple computer-aided detection models to detect possible threats. Fusion and tracking algorithms are used to reduce the number of false alarms. The system has been extensively tested and demonstrated on data from a DIDSON sonar. The ATR system can provide results to the operator in real-time and has demonstrated a clear capability to detect man-made targets on the hull. The ATR system can also provide target information to SeeTrack Offshore, which in turn can use that information to automatically manoeuvre the ROV around the targets in order to gain more views of the potential threat. The information can also be used to guide the ROV back to the targets at a later stage of the inspection process. Figure 3 shows a sequence of ATR results obtained during a hull inspection.

Ensuring Full Coverage

Inspecting the hull as a whole is an important part of the process. To do

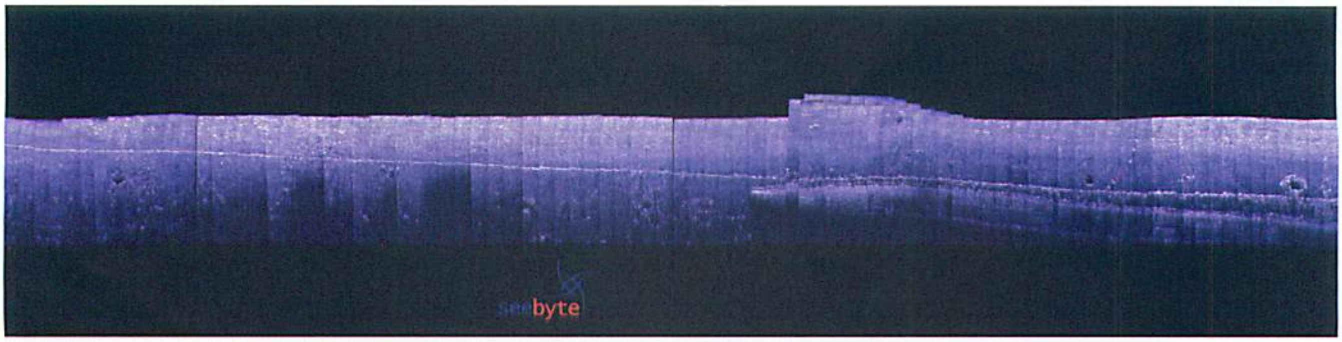

Figure 4: 200m mosaic of a ship hull that can be generated in real-time as the vehicle is carrying out its inspection mission.

this, it is important to provide the user with an overview of the area that has been inspected and to provide information on the hull coverage. A real-time mosaicing algorithm has been developed that provides a single, integrated view of the hull. The mosaic enables the operator to view where the possible mine threats are in relation to the whole hull rather than viewing the hull as a series of isolated sonar frames. The mosaic shows the operator which regions of the hull the vehicle has inspected and where it still needs to go. This process ensures that there are no gaps in the data.

Figure 4 shows a real-time mosaic carried out while inspecting an aircraft carrier using Bluefin's HAUV at this year's AUV fest held at Newport Rhode Island in May. The HAUV is a hover-capable AUV designed to carry out hull inspections equipped with a DIDSON sonar. The mosaic was built in real-time and demonstrated during the event.

Future Work

A number of challenges still need to be faced in order to make full autonomous inspections a reality. Automatically detecting changes to the hull as subsequent inspections are carried out is one such challenge. Automatic change detection can be used to efficiently and expediently report to the operator potential areas of concern. In order to meet that challenge, the position of the UUV with respect to the hull must be known precisely. This is a complex problem if the shape of the hull is not known a priori. SeeByte is currently working alongside Bluefin Robotics, Massachusetts Institute of Technology (MIT) and Florida Atlantic University within the Confined Area Search Program funded by the Office of Naval Research to meet these problems.

The Authors

Dr Scott Reed obtained a Masters degree in Astrophysics from the University of Edinburgh in 1999, and then completed a Masters degree in Information Technology from Heriot-Watt University in 2000. In 2003, he completed a PhD from the same University at the Ocean Systems Laboratory, a recognised centre of excellence in the provision of autonomous technologies for underwater vehicles. His doctorate thesis was titled *Automatic detection and classification models for sidescan sonar imagery.* The research specialised in automated detection and classification techniques for side-scan sonar systems. In 2005, he was an invited scientist at the NATO Undersea Research Centre in La Spezia (Italy). Scott is a development manager at SeeByte Ltd.

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