UMS Mission Management for Mixed Fleets

Dr. Chris Haworth, Dr. Jonathan Evans
SeeByte
Edinburgh, UK
chris.haworth@seebyte.com,
jonathan.evans@seebyte.com

Dr. Kier Dugan, Dr. Ze Ji
ASV, Portchester, UK

Dr. Stephen Cotterell
Marine Biological Association of the UK, Plymouth, UK

***Abstract*— SeeByte have developed a suite of tools to enable command and control of off-board autonomous systems. This includes SeeTrack, a top-side mission tool suit, and Neptune, a multi-vehicle autonomy system. The application of these tools, with a particular focus on in-mission adaptive and autonomous behaviors, is being investigated for use in oceanographic and environmental research scenarios.**

"*Autonomous systems have the potential to revolutionize the conduct of maritime and amphibious warfare. This transformation could be as dramatic as the move from sail to steam, the invention of the submarine or the advent of naval aviation*" First Sea Lord, Royal Navy

This transformative potential also applies to a wide range of maritime activities, including hydrography, oceanography and environmental research. However, it is clear that to gain the best advantages for scientific research the latest autonomous systems and technology needs to be made available to a wider pool of users. In particular, the current quantity and quality of data available to scientific research is limited in many aspects. The overarching aim for the delivered software framework and the scenario behaviors will be to enable maritime autonomous systems to be the "force multiplier" required. Particular focus will be given to ensure that the behaviors developed are capable of reducing the frequency and complexity of operator input and to enabling shore-based operations with very long duration missions.

This paper will present two on-going pieces of work, giving some insight in to the technology developed and some initial results from the programs.

The first is the Adaptive Autonomous Ocean Sampling Networks (AAOSN) project, which is a £1.5million project run by NERC, Dstl and the Innovate UK, to develop new technology solutions for coordinating a suite of Marine Autonomous Systems (MAS) enabling tracking of dynamic features. The SeeByte consortium, which comprises ASV and Marine Biological Society of the UK, aims to provide an open software tool-set and user interface that will enable improved use of a wide-range of autonomous systems in gathering data from the ocean over extended periods, while constantly adapting to the environment and mission requirements.

The behaviors will integrate sensor data and interpretation methods to enable adaptive, multi-vehicle missions using combinations of USV, UUV and Glider assets. Particular focus will be on extending the existing work on Tagged Fish Tracking, to develop a multi-vehicle approach with a ten-day in-water field-trial occurring in the Plymouth Sound.

The second program of work discussed is development of a SeeTrack glider-fleet management tool that can remotely monitor the position of each glider in the fleet and re-plan and change mission plans accordingly. This effectively provides a tool where every glider's vital stats can be monitored and tasking updated in one place. This can be done from a remote laptop at any time of day. This tool was originally developed for the NOC MARS (Maritime Autonomous Remote Systems) team and will provide remote mission planning capabilities, as well as enabling 24/7 remote monitoring for the UK National Facilities glider fleet managed by NOC.

Keywords—UUV, Glider, Mission Management

I. Introduction

Unmanned Underwater Vehicles (UUVs) are widely made use of within the maritime community. They offer many advantages over traditional methods for exploring deep and hard to reach environments. Long endurance vehicles such as subsea gliders also offer the capability to explore further afield than ever before. However, there are common limitations which often impede operations and prevent operators from using UUVs to their full potential. For example, an oceanographic region survey to gather sample data should be capable of using all the vehicles regardless of their type. However, these vehicles have dramatically different characteristics (speed, endurance, depth rating, communication, payload type, navigation suite) and this presents significant challenges in the design of the system. Likewise, heterogeneous fleets of UUVs require operators to be familiar with the particulars of each manufacturer's operating system. As fleets expand, this can be costly and impractical.

There have been several developments in software solutions to enhance the capabilities of UUVs. Tools have been designed to enhance the autonomous capabilities of off-board assets, allowing vehicles to become more operator-independent. Additionally, software solutions have been designed to overcome some common limitations of UUVs: shared interfaces for multi-vehicle fleets allow for larger fleets and greater output whilst decreasing operator workload.

This paper will present two on-going pieces of work, giving insights in to the technology developed and some initial results from the programs.

978-0-933957-43-5 ©2015 MTS

II. GLIDER FLEET MANAGEMENT

Gliders are becoming the tool of choice for a broad range of physical oceanographic tasks. These vehicles offer can offer significantly greater sampling and area coverage. Achieving the same results with traditional methods would be impractical or economically unsupportable. The Marine Autonomous and Robotic Systems (MARS) group in the National Oceanography Centre (NOC) manage a fleet of unmanned vehicles consisting of autonomous underwater vehicles (AUV) built by NOC, gliders from Kongsberg and Teledyne Webb, and Unmanned Surface Vehicle (USV) systems from ASV, MOST AV and Liquid Robotics. Though the mission plans consist primarily of a sequence of waypoints, this fleet currently requires experienced operators, careful monitoring and regular control.

However, the use of these vehicles can often be limited by labor intensive procedures that are required to update and monitor the glider's vital stats. This may mean a 24-hour support team for each vehicle. Each of the unmanned vehicles is equipped with its own user interface requiring the operators to learn tools developed by the original manufacturers. Glider operators work in shifts and a single operator is typically capable of supervising and managing a maximum of four gliders at any one time. As a result, managing a large fleet of gliders typically requires a large support team meaning it can often be a costly endeavor. This is unsustainable as the fleet grows in numbers with the result that operational results can produce less than optimal data collection or area coverage.

Similar limitations have been observed with AUVs. Commercial suites of tools were originally developed to enable command and control of off-board autonomous systems to combat these issues. These software solutions effectively provide a fleet management system by allowing multiple AUVs, including their sensor feeds, to be managed from one common interface. Entire fleet's navigational information and vitals can be viewed in a single clear consolidated picture. These concepts have been built upon to provide fleet management tools for subsea gliders which will allow vehicles to collaborate and adapt their missions autonomously according to the position and goals of each glider in the fleet. This includes a top-side mission tool suit and a multi-vehicle autonomy system. The applications of these tools, with a particular focus on in-mission adaptive and autonomous behaviors, are being investigated for use in oceanographic and environmental research scenarios. By taking these field-proven AUV tools and adapting them to oceanography requirements, it is hoped to offer the same advanced capabilities including fleet management systems, in-mission adaptive autonomy and inter-vehicle collaboration.

This top-side mission tool is a modular mission planning, monitoring and post processing tool for rapid on-site analysis and data fusion of sensor data, including side-scan, imaging sonar and video. It uses a modular Service Oriented Architecture (SOA) and provides a distributed, networked environment that uses open web services to allow third-party extensions. It is uses the Open Geospatial Consortium (OGC) standards to ensure broad compatibility and provides a single integrated interface with the ability to call on advanced signal and sensor processing modules. The top-side mission tool provided the base of the NOC glider-fleet management system to allow rapid development of the specific glider functionality.

The glider fleet management tool enables users to remotely monitor the position of each glider in the fleet and re-plan and change mission plans accordingly. Every time the glider communicates with the shore-side base station, the logs are automatically processed. Tasking is queued for each glider, and if there is no error present the glider will continue onto the next task in the queue. If there is an error, this can be communicated to the operator on duty via text or email. This effectively minimizes the need for constant monitoring of the operating systems of the gliders while waiting for a surfacing update. Surface shipping can be a danger to surfaced gliders or AUVs so it is important that operators minimize the time that a vehicle spends above the water. At the surface, if the system is in an error state that is not terminal to vehicle then the pilot is able to command the vehicle to submerge and therefore prevent surface collision risk.

The glider-fleet management tool also enables remote access to the core database, which is located in NOC (Southampton), allowing operators full capability to monitor and task gliders from any location. For example, operators may be logged in at NOC, in a temporary mission control room or even from their own home. They retain full ability to deal with any issues that arise regardless of their location.

The aim for this work, which is currently undergoing extensive testing by NOC, is to allow larger fleets of gliders to be managed without having to invest in training ever larger teams in the specifics of each glider. This will allow NOC to increase mission durations and fleet size increasing the scope

Fig. 1 NOC Glider used in an experiment off UK coast

(Photo courtesy of NOC)

of scientific and oceanographic missions that can be undertaken

III. Adaptive Autonomous Ocean Sampling Network

A. Overview

The need for adaptive autonomous capabilities for unmanned assets is an area of interest within the oceanographic community. The National Environment Research Council (NERC) and the Defence Science and Technology Laboratory (Dstl), with Innovate UK ran a SBRI (Small Business Research Initiative) competition with funding of £1.45M to develop new technology solutions for coordinating a suite of marine autonomous systems for a range of oceanographic and environmental scenarios. SeeByte, in collaboration with ASV and the Marine Biological Association of the UK were awarded initial Phase 1 proof-of-concept funding (Jan – Mar 2015). This was then followed by a more extensive Phase 2 funding (Jun 2015 – Apr 2016). The consortium's aim is to provide an open software toolset and user interface that will enable fleets of unmanned maritime vehicles to adapt and alter missions according to the external environment.

SeeByte's Neptune software is the core autonomy architecture and this provides goal based mission planning and in-mission adaptive autonomy. There is a clear distinction between goal-based mission planning and straightforward pre-planned missions; goal-based mission planning places an emphasis on the outcome of the mission with the capability for the vehicles to autonomously re-plan the mission to best achieve the intended outcome. In essence, this allows the operator to focus on what the mission outcomes are, rather than how they will be achieved.

The central theme of the program is to develop autonomous behaviors that are independent of the unmanned vehicles used. This requires a modular autonomy architecture that can perform command and control of off-board assets, including in-mission. This autonomy architecture provides a simple way to organize the software modules, interfaces and communication protocols in an autonomous system. The architecture is specifically designed to allow the adaption, upgrade or replacement of components. This effectively enables fleets of heterogeneous assets to be managed and monitored from a single interface. By providing a shared command and control center for fleets of assets, each asset is able to present its capabilities to the mission planner and undertake relevant behaviors accordingly. Finally the autonomous behaviors are designed to be "written once, run many" meaning that the same behavior can run on many different vehicle types.

B. Oil Spill Localization

During Phase I of the project the consortium focused on addressing two scenarios. The first, Oil Spill Localization, adapted existing search algorithms to provide extended-area adaptive search capability that can provide optimal sensor coverage across a broad area. From the data gathered, vehicles in the fleet are able to adapt their paths in order to home in on the most likely source location.

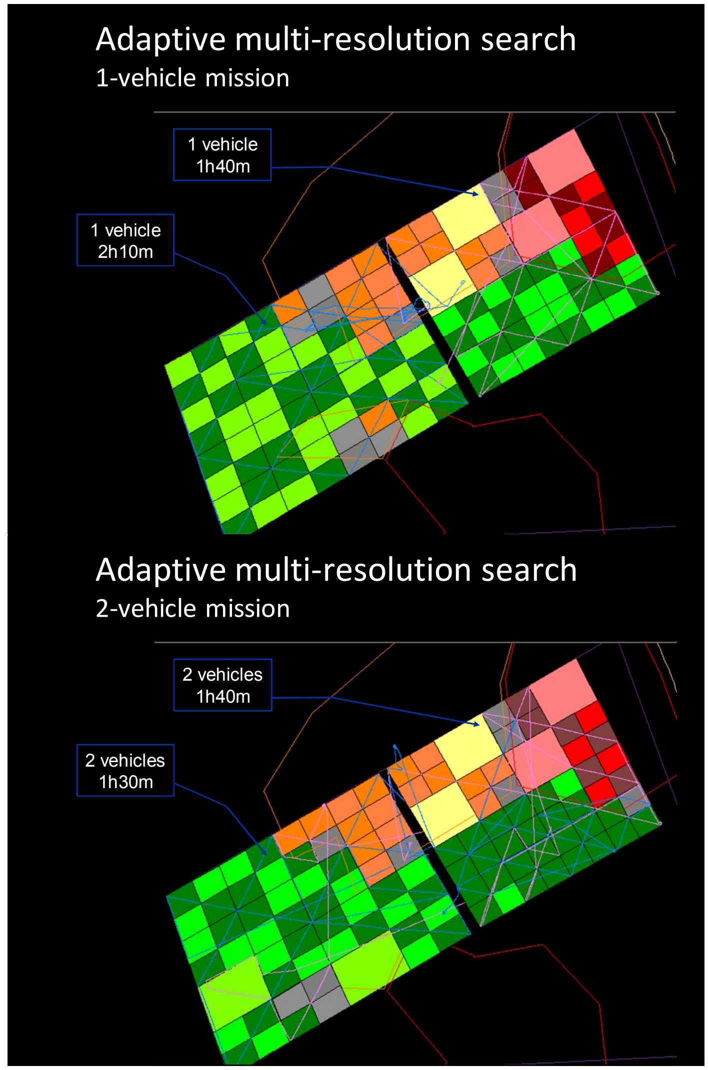

Fig. 2 Adaptive multi-resolution search algorithm

The underlying search algorithm can be tuned to focus on a breadth-first approach or a depth-first approach. A breadth-first approach focuses on identifying trends and concentrations over a large area; a depth-first approach refers to the level of detail and examines areas of interest immediately. The diagrams (Figure 2) show the same search technology being used to assess the seafloor, with certain seabed types classified as higher-priority for searching than other seabed types. For example, the system could be set to investigate flat seabed in detail but to de-prioritize complex areas.

C. Tagged Fish Tracking

The second scenario addressed was Tagged Fish Tracking, which targeted the challenges associated with performing real-time mission adaption to optimize tagged fish encounters. In order to achieve this, the project needed to not only develop a real time interface to the vehicle (an ASV C-Enduro platform) but also develop an autonomous fish tagging behavior which would automatically adapt the vehicles behavior in response to what the vehicle found. The tagged fish tracking behavior that

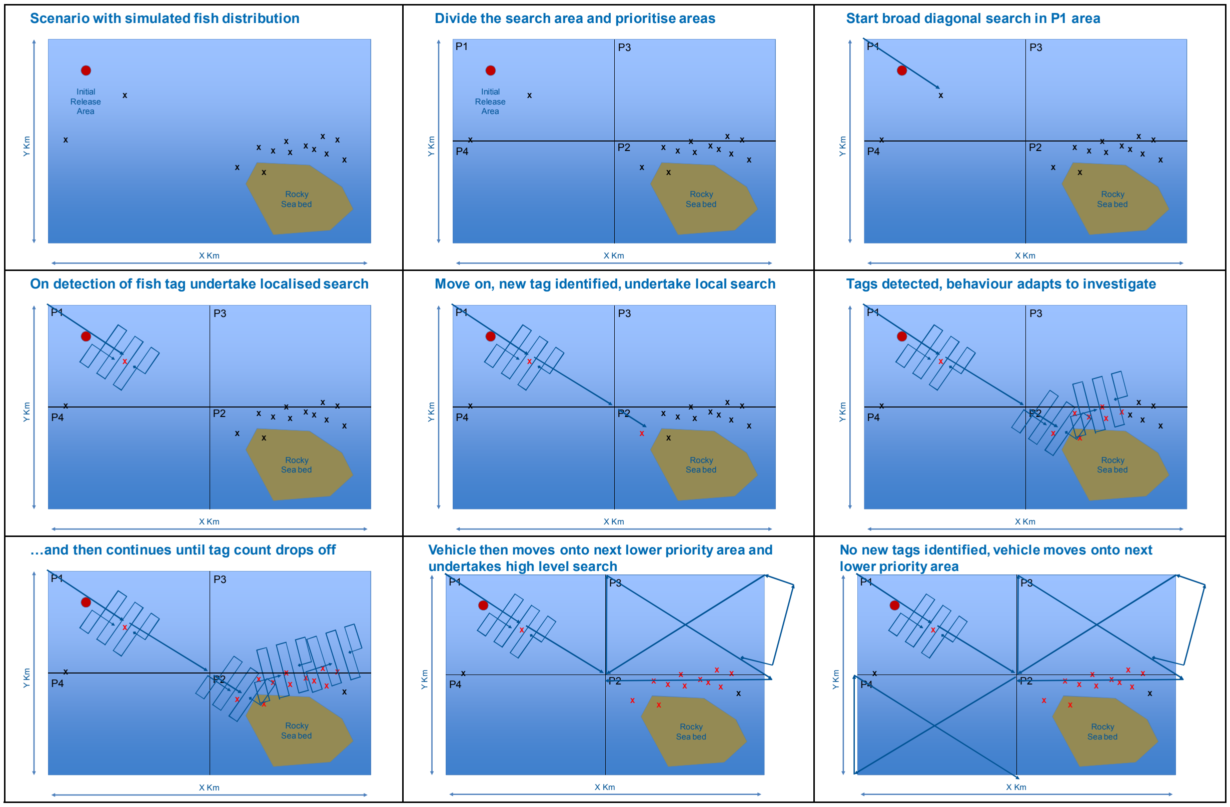

Fig. 3 Tagged fish tracking used at the in-water trial in Stokes Bay (UK). The behavior was run in real-time on-board a C-Enduro USV.

was developed and demonstrated as part of Phase 1 not only demonstrated the ease by which 3rd party vehicles, including NOC's C-Enduro could be integrated into the AAOSN architecture but also demonstrated the ability of the vehicle to autonomously adapt its route according the information received from its onboard sensor to hone in on areas where fish density is likely to be greatest.

Figure 3 shows the fish tagging behavior, developed by ASV using the autonomy architecture, to perform a broad search that, when tagged fish are detected, adapts its mission plan to investigate the local area in more detail. This prototype behavior was run in-water at Stokes Bay, near Portsmouth in the UK, using a USV supplied and operated by ASV identical to the one owned by NOC using simulated fish tags. The behavior's real-time interactions with the ASV and in-mission adaptions were shown to be highly effective.

Delivering a mixture of man-in-the-loop and autonomous control – scientists will be able to leave the maritime autonomous systems to operate over extended periods. The aim is to provide sufficient situational awareness sensors (including collision avoidance behaviors) so that operators can be confident that the systems will do their best to optimize their paths and sensor deployment to meet the science objectives. At any point where communication with the vehicle is available, the scientists will be able to review the mission progress, interact with the collected data before issuing new objectives to the vehicles. Finally the architecture needs to be open so that it provides a toolbox to permit science teams to develop their own novel autonomy behaviors.

Following on from the successful completion of Phase 1, Phase 2 will further develop the two autonomous behaviors for Oil Spill Localization and Tagged Fish Tracking. In addition, behaviors will be developed for Cetacean Tracking, Seafloor Bathymetry Mapping and Tidal Mixing Front monitoring. A program of in-water demonstrations will then test out various aspects of the adaptive autonomy.

IV. Conclusion

This paper has presented two on-going work programs that are aiming to extend the use of unmanned maritime vehicles for use in scientific and oceanographic research. Initial results have been presented showing promising steps towards improved use of unmanned maritime vehicles and further development and demonstrations are planned for 2016.

However, it is clear that to gain the best advantages for scientific research the latest autonomous systems and technology needs to be made available to a wider pool of users. In particular, the current quantity and quality of subsea data available to scientific research is limited in many aspects. The overarching aim for the community needs to be to enable maritime autonomous systems to become the "force multiplier" required. Particular focus should be given to ensure that developments reduce the frequency and complexity of operator input and enable shore-based operations with very long duration missions. This will require many more years of research and development in hardware, software and human-machine interfacing to achieve this vision.

ACKNOWLEDGMENT

SeeByte and ASV would like to acknowledge the support of NOC, Innovate UK, National Environment Research Council (NERC) and the Defence Science and Technology Laboratory (Dstl) for these projects.