NATO OTAN

The Centre Dozen

NURC
PARTNERING FOR MARITIME INNOVATION

September 2010

MOOS: A Powerful Software Platform for Robotic Systems

NURC anticipates NATO's military needs in the maritime environment, in particular the use of robots, such as autonomous underwater vehicles (AUVs) and autonomous surface vehicles (ASVs), for surveillance and operations. As the Centre moves toward more autonomous vehicles, the demand for more sophisticated software increases exponentially. Developers are rapidly moving from programming a single piece of hardware to do a simple task, for example one AUV gathering data in the ocean, to programming multiple assets to complete complex tasks, for example a fleet of AUVs providing coordinated surveillance of an undersea area and making decisions based on the environment.

To speed up the development process, NURC is using open source software called MOOS, which is cross-platform middleware used in robotics system development. Started at MIT's Department of Ocean Engineering and now maintained by the Oxford Mobile Robotics Group, MOOS stands for "Mission Oriented Operating Suite". MOOS was originally developed as software for AUVs but can be used in any environment where multiple applications and operating systems must work together. The interoperability that this allows is of keen interest to NATO militaries trying to integrate and coordinate various hardware platforms that run on different software.

A Simple but Powerful Tool

The MOOS architecture is simple. There is a communication layer and an applications layer. The communication layer includes the MOOSDB hub, which operates like a bulletin board: an application posts data and other applications can subscribe to that data. The data is simply a set of variables that the developers agree upon. The applications layer consists of programs, or modules, to control all aspects of an automated system from logic to sensors to actuators to graphical user interfaces. MOOS comes with a number of standard modules, such as a tool for logging variable histories from the MOOSDB and a utility for launching a batch of MOOS processes. A number of modules are also available that are relevant to operating AUVs, such as a marine multi-vehicle simulator and a remote control interface for manual vehicle control. These standard modules lay the groundwork for developers to create new modules that are specific to their particular system and objectives.

MOOS on board: Decal on NURC's OEX AUV, GLINT '08 sea trial.

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NURC Research Presented at OCEANS '10

Australia, a member of the TTCP (The Technical Cooperation Program), is actively involved in maritime security research. NURC collaborates with Australian defence researchers, especially in harbour protection, In May, NURC researchers were in Sydney to present papers at the Oceans '10 IEEE Conference.

NURC presenters primarily focused on recent advances in antisubmarine warfare and mine countermeasures with an emphasis on cooperative autonomous systems for surveillance, identification and, in the case of mine countermeasures, disposal. Cooperative autonomous systems offer great benefit to NATO militaries, because they can reduce risk to personnel while offering a lower cost alternative to traditional ship-based systems. Presentations included:

Cooperative Anti-Submarine Warfare at NURC: Moving Towards a Net-Centric Capability, Robert Been (presenter), David Hughes, John Potter, Christopher Strode

Using Collaborative Autonomous Vehicles in Mine Countermeasures, Vladimir Djapic, NURC (presenter); Dula Nad, University of Zagreb

False-Alarm Reduction in Mine Classification Using Multiple Looks from a Synthetic Aperture Sonar, Johannes Groen (presenter), Enrique Coiras, and David Williams

NURC researchers were also at the OCEANS '10 MTS/IEEE Seattle Conference to present a variety of topics, including recent developments in the science and technology of the Marine Mammal Risk Mitigation program. This mature program, finishing its tenth year, offers oceanographic researchers the knowledge and tools to conduct active sonar operations in ways that mitigate risk to cetaceans. Presentations included:

Passive Acoustic Monitoring during the Sirena 10 Cetacean Survey, David Hughes, Juri Sildam (presenter), Arnold B-Nagy, Kendra Ryan, and Jeffrey Haun

The Compact Passive Acoustic Monitor: a Tool for Marine Mammal Risk Mitigation, Vittorio Grandi, Piero Guerrini, Stefano Biagini, T. James Osse (presenter), Walter Zimmer

Model Based Decision Support for Underwater Glider Operation Monitoring, Raffaele Grasso (presenter), Daniele Cecchi, Marco Cococcioni, Charles Trees, Michel Rixen, Alberto Alvarez, and Christopher Strode

MOOS, continued from p.1

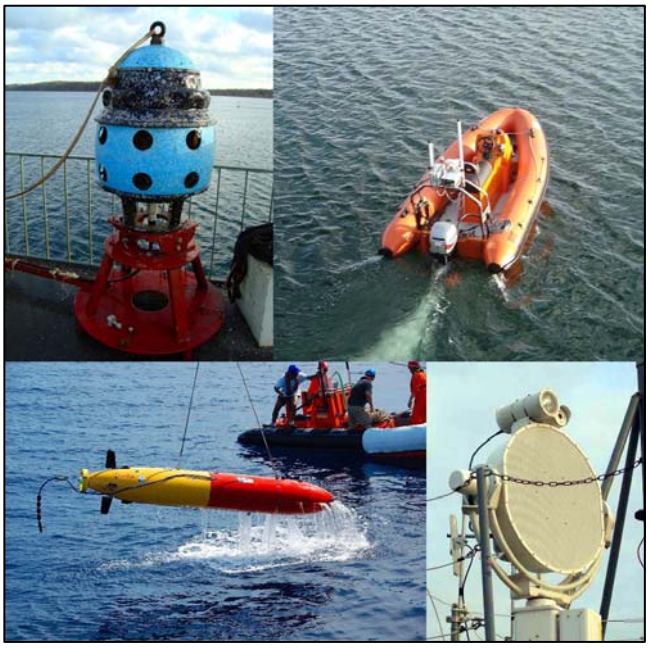
Although MOOS's architecture is simple, the platform is powerful enough to do the types of sophisticated integration and controls that robotics demand. For developers at NURC, much of this power comes from a MOOS package called MOOS-IvP, which includes MOOS and an application called IvP Helm (IvP stands for interval programming). IvP Helm, which was developed at MIT/NUWC (Massachusetts Institute of Technology/Naval Undersea Warfare Center), works just like any other MOOS module. It posts its variables to the MOOSDB, and it subscribes to variables from other modules. The value of IvP Helm is that it offers a set of behaviors that can be used to control autonomous underwater vehicles. Behaviors can be simple, such as maintain a course, or they can be highly complex, such as keep a certain distance and bearing away from a moving object. IvP Helm determines the correct behavior based on data from the environment and then outputs the desired settings, for example speed, heading, and depth.

MOOS at NURC

MOOS is being used at the Centre in a number of different project areas:

- For port and harbour protection, using AUVs, ASVs, and a variety of sensors and warning devices to identify and deter small boats and swimmers from entering a restricted area.
- For mine countermeasures, using AUVs and ASVs to find, identify, and dispose of mines.
- For antisubmarine warfare, using AUVs to gather underwater data and behave in ways that are specific to the current environment and more importantly the anticipated environment.

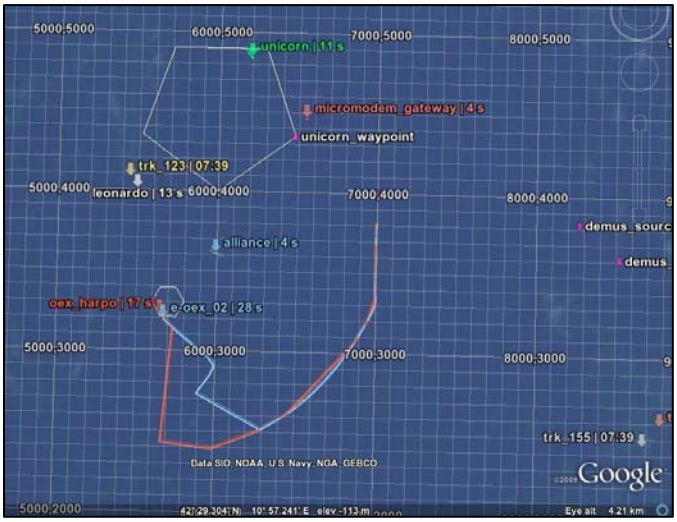
Recently, several NURC staff members participated in the MOOS-DAWG (Development and Applications Working Group) meeting held in Cambridge, Massachusetts. Much of the work that has been done in the last two years at NURC was showcased in a series of presentations. This includes work done by the Cooperative Antisubmarine Warfare Group during the GLINT exercises. GLINT (Generic Littoral Interoperable Network Technology) is a multi-year effort to demonstrate the ability of a network of fixed sensors and AUVs to monitor shallow waters autonomously and intelligently.



MOOS-IvP software runs on a variety of hardware platforms at NURC, including (from top-left clockwise): a fixed sonar diver-detection system, the Mandarina ASV, a long-range acoustic device, and the OEX AUV.

One of the goals of a recent GLINT exercise was to show that AUVs could adapt their behavior based on real-time data gathered from the environment. More specifically, researchers wanted to know if an AUV could use real-time information analyzed on-board to determine the range and bearing of a target as well as position itself to optimally track the target. To answer this question, researchers used the NURC DEMUS sound source and an Ocean Explorer (OEX) AUV towing an array to find and track a target.

The behavior that was developed at NURC aims to improve the localization of a target by keeping the target orthogonal to the AUVs array, which is ideal for sonar performance. As the figure below shows, the OEX AUV was able to find a static target (Leonardo), track it (trk_123), and keep it at broadside, thus circling around the target. Researchers are now exploring the ability of multiple AUVs running MOOS-IvP software to work collaboratively.



The red and blue lines show the OEX's path while optimizing for the target (Leonardo), transmitted from the OEX to the NRV Alliance via two acoustic modems. The jumps in the paths are due to infrequent updates.

Although MOOS clearly shows its value in autonomous vehicle control, MOOS offers benefits beyond hardware control. For example, a new application called pOctaver has been developed at the Centre to help scientists interact with MOOS. Octave is an open-source platform version of Matlab, a modeling program commonly used by scientists. The main purpose of pOctaver is to let scientists run their Octave models on vehicles with MOOS software. Putting scientists into the driver's seat and freeing up developer resources helps make the prototyping process more efficient.

MOOS for NATO

The NATO military is a collaborative and rapidly changing institution. It is also an institution where legacy systems and new systems frequently must be integrated. MOOS is a platform that meets the requirements of this environment. It is a tool for rapid, collaborative development that allows for interoperability of existing and new systems. MOOS is a tool that the Centre will continue to use for rapid prototyping and development and that NATO can use to build the next generation of robotic systems for maritime surveillance and operations.

ACT Partner and National Liaison Representatives Visit NURC

Eleven National Liaison Representatives to HQ SACT and two Partner National Liaison Representatives visited NURC in September to get a deeper understanding of the Centre, its work, and its contributions to naval and maritime security.

NURC Director, Dr. François-Régis Martin-Lauzer, welcomed the group and gave an introduction of the Centre, touching on its widely respected scientific reputation. He noted that scientific and engineering expertise is an enduring strength of the Centre throughout its 50-year history, which has enabled NURC to be a leader in its field even as technologies evolve and political situations and threats change. Chief Scientist, Dr. Thomas Curtin, provided an overview of the Centre's current programme of work, which includes integrated development projects as well as exploratory research projects, all drawing upon and advancing NURC's core competencies in areas such as sensors and signal processing, underwater acoustics, communication engineering, autonomy, and collective intelligence. Deputy Director, Dr. Joseph Arbour, talked to the group about the NURC business plan and hybrid funding model, approved by the NAC earlier this year. Partial customer funding is the Centre's approach to sustain a viable and credible maritime research and technology capability in NATO.

During a tour of NURC research and engineering facilities, representatives demonstrated a good deal of interest in the engineering work, both physical and information technologies such as simulators. This is reflective of national interest in technologies that are more portable, deployable, and affordable, with reduced human risks in force protection. Many of these technologies are either not widely or currently available. Discussions covered not only the technical topics related to future maritime platforms, but also the research function of NURC as opposed to outsourcing research and development to private enterprise, as well as the issue of long-term investment in research and technology when resources are urgently needed in other NATO operations. The visit enabled the delegation to view first-hand the value the Centre brings to maritime security, particularly to those nations that are not as well resourced for research and innovation.

Brigadier General Soren Falk-Portved from Denmark remarked that the visit was very useful in providing insight into the Centre's role in NATO at this time of overall reform and that the group was impressed by NURC's achievements. NURC looks upon the National Liaison Representatives as links to the Nations who can facilitate even closer interaction between NURC and its sponsors and customers.

Visitors take a close look at the latest version of NURC's thin array, which is capable of being towed by unmanned vehicles.

WSS2010 Programme Shaping Up

The 2nd International Conference on Waterside Security (WSS2010) will be held in Marina di Carrara, 3 - 5 November.

Protecting large ports, coastal urban centres, critical infrastructure, and industry located along the water has become one of the greater security challenges. Waterside security includes measures taken to counter maritime terrorists, pirates, smuggling, and human trafficking.

This conference, hosted by NURC, will bring together researchers and security providers, military and civilian, who will present and discuss new technologies and how to transition them into operations.

CDR Stein Olav Hagalid from the Royal Norwegian Navy will speak at the plenary session. As the Branch Head of the NATO Shipping Centre, which interacts with the international merchant shipping community, CDR Hagalid is well positioned to lead the discussion on "Reducing Vulnerability Through Multi-National Collaboration".

In conjunction with the conference, NURC's CORALL program is offering a short course on "Port Security: Basics of Defence Against Underwater Intruders". This course is 1 - 2 November, prior to the conference and will offer an introduction to technologies for security against underwater intruders and hands-on experience of commercially available equipment.

For more info on the WSS2010 conference, go to http://www.wss2010.org.
For more info on the CORALL short course on Port Security, go to http://www.nurc.nato.int/corall/course2010-02.htm.

NURC Collaborates with CANEUS CSSP

The CANEUS Shared Small Satellite For Collective Safety, Security and Prosperity (CSSP) International Workshop will take place in Marina Di Carrara, 20 - 22 October. NURC is partnering with CANEUS to present this workshop, which aims to foster global collaboration to create a concept for space-based communications infrastructure.

The concept involves a network of simple ground terminals and nano-satellites to provide access to "unwired" places: open oceans, polar regions, jungles, and deserts. Access to the entire shared capacity is available to the partner nations that contribute materially to the constellation thus providing a significant return on the individual investment of any participating partner.

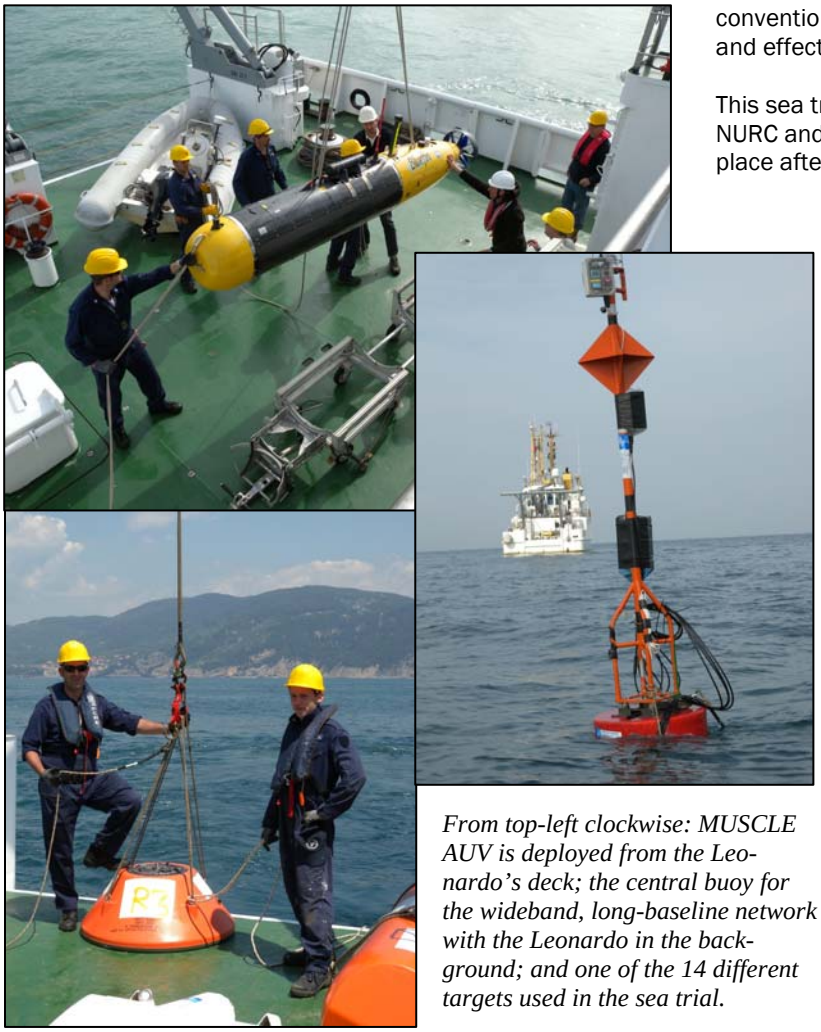
The three-day workshop will develop concepts, timelines and a budget estimate for a low-cost, internationally shared small satellite communications backbone in space with exceptionally low barriers to entry for participating nations.

For more info on CANEUS CSSP, go to http://www.caneus.org/sharedsmallsats/default.aspx.

AMiCa'10 Advances Use of Autonomous Vehicles and Sensing Technologies in Mine Countermeasures

The AMiCa'10 (Autonomous Mine Clearance 2010) sea trial, conducted over the summer, tested multiple components of an end-to-end autonomous mine hunting and neutralization "system of systems". The application of autonomous vehicle and sensing technologies to the naval mine warfare problem will make operations safer by removing ships and personnel from the minefield as well as increasing operational tempo by automating some of the most time-consuming parts of the process. The results of this trial will guide development of the system components to be used in out-year demonstrations of a complete end-to-end system.

The main trial area was the Gulf of La Spezia. The CRV *Leonardo* was used for daily operations, making the roughly one-hour transit each way between the test site and NURC each morning and evening. Several measurement objectives were designed for this sea trial. First, data were collected to support research efforts in autonomous mine detection and classification, including reconstruction of a sea floor object's shape from multiple high resolution synthetic aperture sonar (SAS) views of that object. NURC's MUSCLE vehicle (Mine-hunting UUV for Shallow-water Covert Littoral Expeditions), with its state-of-the-art SAS system, was run against a field of 14 targets at multiple aspects and ranges. The mine collection consisted of some realistic mine shapes, some less realistic exercise mine shapes, and some mine-sized boulders.



From top-left clockwise: MUSCLE AUV is deployed from the Leonardo's deck; the central buoy for the wideband, long-baseline network with the Leonardo in the background; and one of the 14 different targets used in the sea trial.

Data processing started on board *Leonardo* immediately after download from the vehicle and continued as the data was brought into NURC at the end of each day. This capability to visualize intermediate processing results soon after data collection allowed adjustment of measurement geometries as the trial progressed and enabled collection of a rich data set for further analysis. The data will also be used by NURC's collaborators in the Joint Research Project (JRP) on Mine Detection and Classification (with participation from Great Britain, Germany, USA, the Netherlands, Norway, and Belgium) for their research on related topics.

Another primary objective of the AMiCa'10 trial was to exercise a newly installed real-time processing capability on the MUSCLE vehicle and use the output of this processing in-stride to adapt the vehicle's path. This type of through-the-sensor adaptation to the local environment can be a critical capability for environments that evolve rapidly in time or are poorly known *a priori*. By making these adjustments *in situ*, the vehicle can maximize its efficiency and ensure that high-quality data is collected over its entire area of responsibility, thereby enhancing its ability to detect and classify targets. An initial capability for processing raw sensor data, evaluating areas that were covered with appropriate fidelity, and adaptively re-planning missions to attain full coverage was installed and tested during the sea trial. Follow-on work will be done to enhance this capability, and run comparative tests against conventional static mission planning tools to assess efficiency and effectiveness.

This sea trial ushered in a new era of cooperation between NURC and the Italian Navy, being the first sea trial to take place after the recent reflagging of CRV *Leonardo* in which it was introduced into the Italian Navy fleet and manned by an Italian Navy crew. With the help of several short training cruises, the crew was well-prepared for some of the particular requirements that arise in shallow water scientific research activities. The new Italian Navy crew greatly facilitated the at-sea operations, thereby significantly contributing to the scientific objectives of the sea trial.

NURC
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The Centre Dozen is published four times a year in March, June, September and December.

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