A ROS-enabled floating hackathon: coordinating multiple marine robots

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Outline

Introduction to scientific marine surveys

Challenges for robotics in a marine environment

Meet the robots!

- DriX
- Mesobot
- NUI

Collaborative missions

A Maritime ROS Community
Scientific Marine Survey

photo: Laura Lindzey
Bathymetric Mapping

Credit: Ocean Exploration Trust
Water Sampling
photos: Dr. Kylara Martin
Domain-Specific Challenges
No radio? No GPS!

Where am I??
Long Baseline Localization

Acoustic triangulation using two-way travel time to multiple beacons.
Ultra-Short Baseline Localization (USBL)

A single transducer with multiple elements uses relative phase to calculate arrive angle and two-way travel time for range.
Doppler Velocity Logger (DVL)

Measure velocity relative to seafloor using doppler shift of 4 sonar beams
What is my robot doing?

No radio? No WiFi!
Tether
Acoustic Communications
“...accelerate exploration through the development of new ocean technologies and operational concepts...”

ROS Contribution:
- Connecting the community
2022 NOAA OECI Technology Integration Cruise

**Where:** In the waters off the Hawaiian Islands

Credit: NOAA ENC Viewer
E/V Nautilus

Our mobile base of operation was the E/V Nautilus operated by the Ocean Exploration Trust.

- Length: 68 meters (224 feet)
- Complement: 17 crew; 33 science and operations
- Endurance: 40 days at sea

https://nautiluslive.org/tech/ev-nautilus

Credit: Ocean Exploration Trust
Meet the robots!

On the surface: DriX

Seafloor: NUI

Midwater: Mesobot

Credit: Ocean Exploration Trust
DriX

Production uncrewed surface vehicle produced by iXblue that specializes in mapping the seafloor and the watercolumn.

Communicates with operators using:

- Wifi (within 1 km)
- MBR (within 20 km)
- Iridium (global).

Perception sensors include:

- Cameras
- Lidar
- Radar
- Automatic Identification System (AIS)
DriX Science payload includes various sonars to:

- Map the seafloor (2040 MBES)
- Detect what’s in the water (EK80)
- Track and communicate with underwater robots (USBL)
DriX - Looking into the water

Simrad EK80 Scientific Echosounder

- Single beam looking down in the watercolumn underneath DriX
- 200 kHz (returns get noisy at depths of 200 meters and beyond)
DriX - Looking into the water

ROS driver developed using new RawSonarImage message.

ROS Contributions:
- Platform for developing common acoustic messages
- Existing transformations and visualization tools provide good payback for relatively low cost of writing a driver
DriX - Software

Delivered with a ROS1 based software system

- Closed source, but uses open source drivers developed at WHOI and UNH
  - MBES driver developed at WHOI
  - Radar driver developed at UNH
- iXblue has contributed back to those packages.

Project11 added by UNH to extend factory capabilities

- Can “drive” DriX by sending paths
- Interfaces with added payloads
- Links to operator interface (CAMP) via udp_bridge.

ROS Contributions:

- Open framework allows vendor to use community developed hardware drivers and contribute back.
- Easily interface existing ROS based Project11 with this new robot.
DriX - Nautilus communication

Select topics transmitted over MBR link using udp_bridge.

udp_bridge is robust to intermittent connections and supports throttling.

ROS Contributions:
- udp_bridge uses ROS message serialization
- iXblue software and UNH Project 11 share ROS cores
- Communication between iXblue and UNH systems is trivial
NUI

Hybrid ROV/AUV

- Optional bare fiber tether (fragile!)
- 3x acoustic modems
  - 3.5 kHz Micromodem
  - 10 kHz Micromodem
  - Sonardyne
- Norbit multibeam
- Multiple cameras
- RDI Doppler Velocity Logger

Photo: Laura Lindzey
NUI’s software

LCM + ROS

- Legacy
- Core functionality
- Instrument Drivers
- Research / Tech Demonstrations
Mesobot

- Purpose is to study life in the ocean twilight zone (where light can still reach)
- Mesobot was carefully designed to avoid disturbing the animals it observes.

- https://twilightzone.whoi.edu/work-impact/technology/mesobot/

Credit: WHOI Mesobot Team
Mesobot

- Mesobot carried a sampler that pumps seawater through filters to collect environmental DNA—or eDNA—traces of DNA that were left behind by animals recently in the area.
- Very good depth measurements, knows heading, but not position.
Mesobot

- NOT ROS base, custom software.
- Designed to follow a mission script with limited operator interaction
- Tracking position and receiving status updates are optional, but very desirable!
- Can accept limited commands
  - set heading
  - go to depth “x”
  - move for “n” seconds
  - Run sample pump “y”

Credit: WHOI Mesobot Team
3 Example Missions

- Mesobot + DriX (providing
- NUI - nested survey
- NUI + DriX (comms relay)
Maritime Broadband Radio (MBR)
10 to 14 Mbps up to 20 km IP link

Payload Computer
UNH Project 11

Main Computer
iXblue Software

Basic commands

iXblue (HMI)
Human Machine Interface

Position updates
- about every 5 seconds

UNH Project 11
Operator Station

Ultra Short Base Line (USBL)
acoustic tracking and communication
- Range up to about 3000 meters

Status message
- about 30 bytes
- sent twice a minute

WHOI Software
Simple ASCII Interface
Mission 1: Mesobot + DriX
Mission 1: Mesobobot - DriX - Nautilus communication

Driver on DriX interfaces USBL with ROS

- Converts positions to geographic_msgs/GeoPoint messages
- Passes ASCII data using std_msgs/String messages

ROS node on DriX converts Mesobot status to Project 11 Heartbeat message
Mission 1: DriX augmenting Mesobot’s range and situational awareness

1. Scientists determined where to sample using data from DriX’s sonar.
2. Mesobot was commanded to go to the target depth.
Mission 1: DriX + Mesobot

DriX transits to Mesobot’s position
Mission 1: DriX + Mesobot

DriX sees Mesobot in sonar data.

Confirms that Mesobot is swimming up to the target depth.
Mission 1: DriX + Mesobot

Mesobot reaches commanded depth.

DriX shows an offset between the layer of interest and Mesobot’s position.
Mission 1: DriX + Mesobot

Command was sent to Mesobot to fine-tune target depth.

Mesobot was then commanded to sample for eDNA by pumping water through a filter.
Mission 2: CoExploration
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Mission 2: CoExploration
Mission 2: CoExploration Architecture
Mission 2: ros_acomms
Mission 2: NUI Nested Survey
Mission 2: Follow-up camera survey
Mission 2: Progressive Image Transfer
Mission 3: DriX + NUI
Mission 3: DriX + NUI

I'm done!
Mission 3: DriX + NUI
Mission 3: DriX + NUI
Mission 3: DriX + NUI
Mission 3: Modem Agnostic Operation

WHOI MicroModem2  Sonardyne AvTrak6

Image: Gallimore et al. 2010

Image: Sonardyne.com
Mission 3: Modem Agnostic Operation

WHOI MicroModem2

Sonardyne AvTrak6

Image: Gallimore et al. 2010

QueueTxPacket.srv

ReceivedPacket.msg

QueueTxPacket.srv

ReceivedPacket.msg

Image: Sonardyne.com
Conclusions

• ROS is being used operationally in the ocean
• The motivation for using ROS in marine applications has matured from “providing necessary infrastructure” to “enabling collaboration and code sharing”
• Efforts to standardize messages/drivers are starting to pay off in collaborations across institutions
Code Availability

Both Vehicles

- [github.com/apl-ocean-engineering/hydrographic_msgs](https://github.com/apl-ocean-engineering/hydrographic_msgs)
  - Community effort to standardize messages, starting with acoustic sensors
- [github.com/rolker/sonardyne_usbl](https://github.com/rolker/sonardyne_usbl)
  - Sonardyne driver, compatible with ros_acomms
- [bitbucket.org/whoidsl/ds_sensors/](https://bitbucket.org/whoidsl/ds_sensors/)
  - Includes drivers for a variety of marine instruments, including NUI’s RDI DVL
- [https://github.com/uri-ocean-robotics/norbit](https://github.com/uri-ocean-robotics/norbit)
  - Multibeam driver compatible with hydrographic_msgs
- [git.whoi.edu/acoms/roa_acoms.git](https://git.whoi.edu/acoms/roa_acoms.git)
  - Manage acoustic comms: modem driver, queue manager, TDMA, message encoding
- [bitbucket.org/whoidsl/coexploration](https://bitbucket.org/whoidsl/coexploration)
  - Tools to transfer images, multibeam maps, and time series data
- [https://github.com/CCOMJHC/project11](https://github.com/CCOMJHC/project11)
  - Marine robotics framework focusing on seafloor mapping
- [https://github.com/CCOMJHC/halo_radar](https://github.com/CCOMJHC/halo_radar)
  - Driver for HALO series of marine radars
- [https://github.com/CCOMJHC/simrad_ek80](https://github.com/CCOMJHC/simrad_ek80)
  - Echosounder driver compatible with hydrographic_msgs

NUI

- [https://github.com/uri-ocean-robotics/norbit](https://github.com/uri-ocean-robotics/norbit)
  - Multibeam driver compatible with hydrographic_msgs

DriX

- [https://github.com/uri-ocean-robotics/norbit](https://github.com/uri-ocean-robotics/norbit)
  - Driver for HALO series of marine radars
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  - Echosounder driver compatible with hydrographic_msgs
Thank you!