Mapping the seafloor with ROS using Project11

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- **Used on multiple vehicles**
- **Beyond seafloor mapping, used to collaborate with underwater robots.**
  - See “A ROS-enabled floating hackathon: coordinating multiple marine robots” presented at ROSCon 2022
The unique challenges of seafloor mapping with a robot

For the purpose of updating nautical charts, surveys are typically done from a surface ship using a Multibeam Echosounder or Sidescan Sonar

Credit: NOS/NCCOS/CCMA
The unique challenges of seafloor mapping with a robot

Coverage is often obtained by running parallel lines within a survey area

- This is often compared to “mowing the lawn”
The unique challenges of seafloor mapping with a robot

Surface robots and underwater robots can both be used for seafloor mapping.

Surface robots have the following advantages when used for hydrographic surveys:

- Direct use of GPS allows more precise and accurate positioning
- Can survey in more shallow water which are the areas more in need of mapping
The unique challenges of seafloor mapping with a robot

Navigating on water

- Nautical charts show where it should be safe to navigate
  - Does not show dynamic obstacles such as traffic, fishing gear, or floating debris
- COLREGs are the rules used to prevent vessels from colliding
  - Designed for humans
  - Not always followed to the letter
- For situational awareness, human mariners use radar, radios, AIS as well as their eyes and ears.
  - Automatic Identification System (AIS) is used by some ships to automatically transmit their position
The unique challenges of seafloor mapping with a robot

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Diving into Project11 - Goals

Take baby steps towards autonomy

Use the building blocks of a future autonomous system as tools to reduce operator workload now.

Example: Detecting potential obstacles to display to an operator in the short term can lead to detecting obstacles to feed to a future autonomous navigation stack.

Equivalent to automobile technology such as adaptive cruise control and lane keeping eventually leading to full self driving cars.

Practical Autonomy!
Diving into Project11 - Goals

Allow fewer operators to manage more robots

As tools are added to reduce workload, more robots could be managed by fewer operators.

Take incremental steps towards having a fully autonomous fleet.
Diving into Project11 - Goals

Provide a framework where ideas can be tested

- Students can test algorithms
  - Alex Brown developed a path planner to efficiently cover survey lines while avoiding dynamic obstacles as his Master’s project
- Good ideas get adopted by industry (we’ll see some examples later!)
Diving into Project11 - Concepts

Platforms: Have a location/pose and can be tracked

- For example, a ship where an operator may be located
- Can be represented in a TF tree
- Enables robots to collaborate with crewed boats for example
- May have sensors
Diving into Project11 - Concepts

**Robots:** Platforms that may be commanded to accomplish tasks

Would typically run a ROS core
Diving into Project11 - Concepts

**Tasks:** Goals that are higher-level than simply reaching a position/pose.

A survey line, for example, may have constraints on how it should be followed, for example:

- Off-track error must be less than x meters
- Rate of turn must be less than y degrees per second

Example tasks:

- Transit to a position (like the global planner in the ROS Navigation stack)
- Survey some lines
- Survey an area
- Follow a platform
Diving into Project11 - Concepts

Multi-robot support

Unique namespace per robot or platform allows topics to be combined

/ben/gps_position  udp_bridge  /nautilus/gps_position
/ben/gps_position
Diving into Project11 - Concepts

Multi-robot support

TF frame ids use prefixes, typically the namespace, to allow TF trees to be combined

```
lookupTransform("ben/base_frame", "nautilus/base_frame");
```
Diving into Project11 - Concepts

Multi-robot support

Relevant topics from other robots may be transmitted via the udp_bridge to be re-published locally.

\[ /\text{ben/gps\_position} \quad \text{udp\_bridge} \quad /\text{drix08/gps\_position} \]

Task: Follow Ben
Diving into Project11 - Components

The operator’s interface: camp

The CCOM Autonomous Mission Planner (camp) displays platforms and robots on a common map.
Current Line
Survey area

Range: 3318 m, Bearing: 239 degs

Surveying mode: autonomous
RPM: 2502
rudder_angle: 3.71699
fuel_level: 96
drive_mode: Auto
der: Forward
rudder: Down

Last HD: 0.0596412s Latency: 9.000547886s

Display:
Distance: 27089 (m) 1456 (mm)

Line length: 4266.19
Total width: 1564.2
Line spacing: 250
First line heading: 41
Robot status

Autonomous

- piloting_mode: autonomous
- RPM: 2502
- rudder_angle: -3.71699
- fuel_level: 96
- dirx_mode: Auto
- emergency: False
- clutch: Forward
- keel_state: Down
- Last HD: 0.0598412s Latency: 0.0000547886s
Background: any georeferenced image supported by GDAL
E/V Nautilus
Platform where operators are located
DriX: Surface robot
Communicates with Nautilus via radio IP link
Mesobot: Underwater robot
Communicates with DriX via an acoustic link
NUI: Underwater robot
Communicates with Nautilus using DriX as relay
Diving into Project11 - Components

The operator’s interface: camp

Used for planning a mission and sending it to the robot.

The 3 click survey pattern is an example of quick way to lay out a survey.
First click: One corner of the survey area
Second click: Opposite corner of the survey area
Third click: Line spacing and direction
Diving into Project11 - Components

Linking the robots: udp_bridge

Node that transmits messages from select topics to a remote machine and locally publishes received messages. Used to bridge data between different ROS cores over unreliable and/or low bandwidth connections.

- Uses UDP to quickly recover from intermittent links
- Uses existing ROS serialization and compresses the data
- Can throttle topics
- Reports bandwidth usage
Diving into Project11 - Components

The robot’s navigation stack: project11_navigation

Similar idea to move_base_flex, but expands beyond a goal pose by supporting various tasks.

- Can use nav_core plugins
- Can use costmap_2d plugins
  - Plugins have been developed for radar data and nautical chart data
- Supports tasks other than “reach a goal pose”, for example:
  - Cover a survey line
  - Survey an area
Diving into Project11 - Components

A controller that adjusts for winds and currents: path_follower

- Existing controllers for land based robots struggled when drifting off line
- Uses a simple PID to calculate a heading correction (crab angle) to minimize cross-track error.

Course: 50 degrees
Cross-track error: 2.4 meters
Crab angle: -12 degrees
Robot heading: 38 degrees
Diving into Project11 - Components

Robot specific controls: helm nodes

A type specific helm node provides the interface between a class of robots and Project11.

- Adapt twist messages or throttle/rudder messages to robot specific APIs
- Receives robot status information which is used to generate periodic heartbeat messages
Diving into Project11 - Components

Simple simulation

A simple, light weight robot boat simulator as a ROS node implemented in Python.

- Allows for the basic system to be tested.
- Does not simulate sensors or groundings

Project11 also works with other simulations:

- iXblue’s DriX simulator
- ArduPilot simulator
- Gazebo
Diving into Project11 - Supported Robots

**L3Harris C-Worker 4**

ASV Ben was Project11’s initial target. Factory software runs a ROS node that connects to a customer supplied ROS core and listens on a topic for throttle and rudder commands.

[github.com/CCOMJHC/cw4_helm](https://github.com/CCOMJHC/cw4_helm)
Diving into Project11 - Supported Robots

iXBlue DriX

Factory software built on ROS and incorporates ideas from Project11. Listens on a topic for path segments to allow driving from an external machine.
Diving into Project11 - Supported Robots

Seafloor Systems Echoboat

The Echoboat is equipped with an ArduPilot based system. A simple interface using mavros connects the Echoboat to Project11.

github.com/CCOMJHC/echo_helm
Diving into Project11 - Supported Robots

Teledyne Z-Boat

Project11 interfaces with the Z-Boat by sending PWM values over a serial line to control the two thrusters and a steering servo.

github.com/CCOMJHC/zboat_helm
Diving into Project11 - Outside users

Global Foundation For Ocean Exploration

GFOE adapted Projec11 to work with the R/V Annie, a crewed research platform capable of interfacing with a backseat driver.
Diving into Project11 - Outside users

University of Delaware

Undergrads Grant Otto, Kleio Baxevani and Owen Li used Project11 on a Seafloor Systems Echoboat for their senior project.
Contributions to the Community

Ideas which made it to industry

- Handling unreliable networks between operators and robots
- Quick goto
- More efficient line planning
Contributions to the Community

Resulting Open Source drivers

The following packages do not depending on Project11 so are useful to the wider community

- Halo radar
  - Rqt plugin
- POSMV
- Sonardyne USBL
- Kongsberg_em_control
  - Not to be confused with kongsberg_em_driver
- Simrad EK80
  - Uses newly defined sonar message
  - Rviz plugin
Collaboration opportunities

Standardizing messages

Workshops and discussions are happening, identifying the need for common messages. A start with acoustic_msgs.

More are needed for marine specific sensors such as radar and AIS. (see ROS Discourse)
Collaboration opportunities

Incorporating emerging research

For example, I’m investigating recent perception work done at UMass Lowell

Do any of you know of existing capabilities that would fit?
Collaboration opportunities

Playing nice with others!

Project11 is evolving to better align with existing ROS standards.

As marine robotics matures, Project11 is used to test and help define new standards.

How can we make various marine robots capable of cooperating across frameworks with minimal effort?
Collaboration opportunities

Making it easier for others to use this technology

Efforts are underway to improve modularity so more parts of Project11 can be used independently in more projects.

Do you see a component you could use but it’s too tied into Project11? Let me know and I can help you untangle it!