Using MOOS-IvP and Goby2 to Adapt Acoustic Data Rates for Improvement of Bandwidth in Collaborative AUV Missions

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Inspiring Minds

Outline

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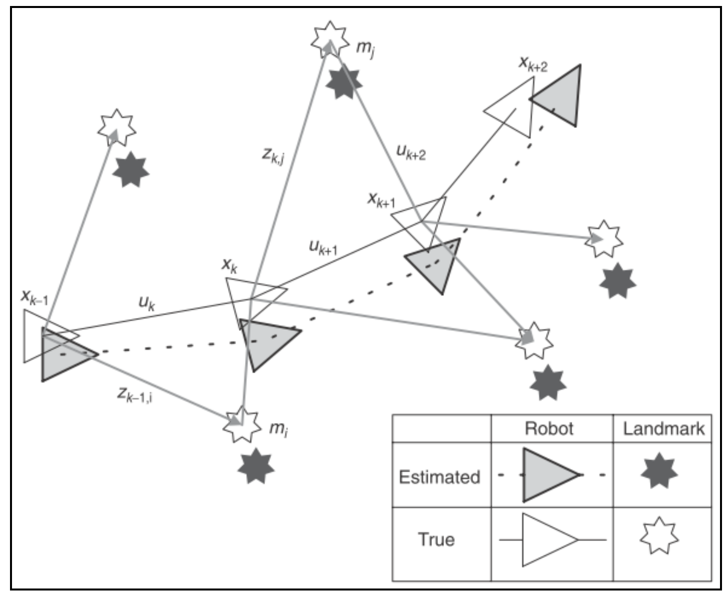
Background
Mine Countermeasures Missions (MCM)

- Mine countermeasures missions are used to locate and neutralize anti-ship mines.
- To successfully search for mines an AUV must be able to:
  - Localize itself
  - Detect mines
  - Generate a map
- Mine hunting in large areas can be made faster by having multiple AUVs cooperate.
- My focus is on improving the localization and map-making for multiple AUV missions.

Background
Simultaneous Localization and Mapping (SLAM)

- The SLAM problem requires a vehicle be capable of entering an unknown environment and building a consistent map while simultaneously locating itself within the map.
- Numerous single-vehicle flavours of SLAM have been implemented on aerial, terrestrial, and underwater robots.

Basic SLAM Map-Making [1]

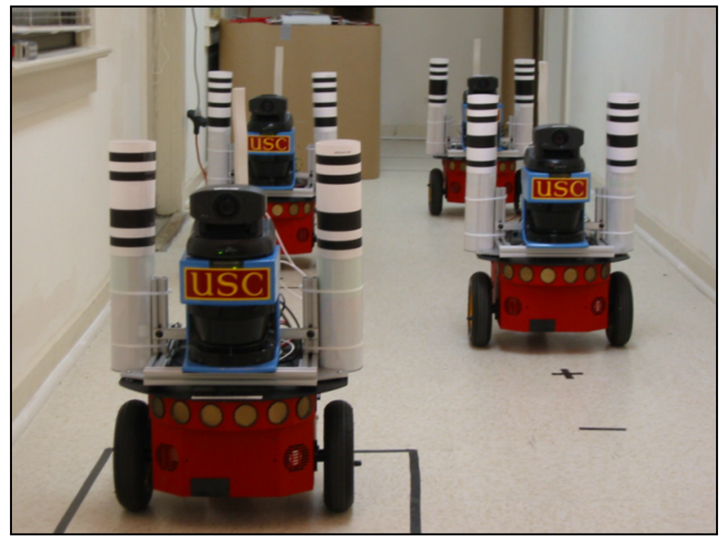


[1] Durrant-Whyte & Bailey, "Simultaneous Localization and Mapping: Part I," IEEE Robotics & Automation Magazine, vol. 13, pp. 99-110, June 2006.

Background
Multi-Vehicle SLAM

- The SLAM algorithm can be extended across multiple vehicles.
- Collaborative SLAM has been successfully implemented by several researchers to teams of terrestrial and of aerial vehicles.
- It has not been successfully implemented underwater.
- The primary obstacle is the poor quality of acoustic inter-vehicle communications

Multi-Vehicle Terrestrial SLAM Robots [2]

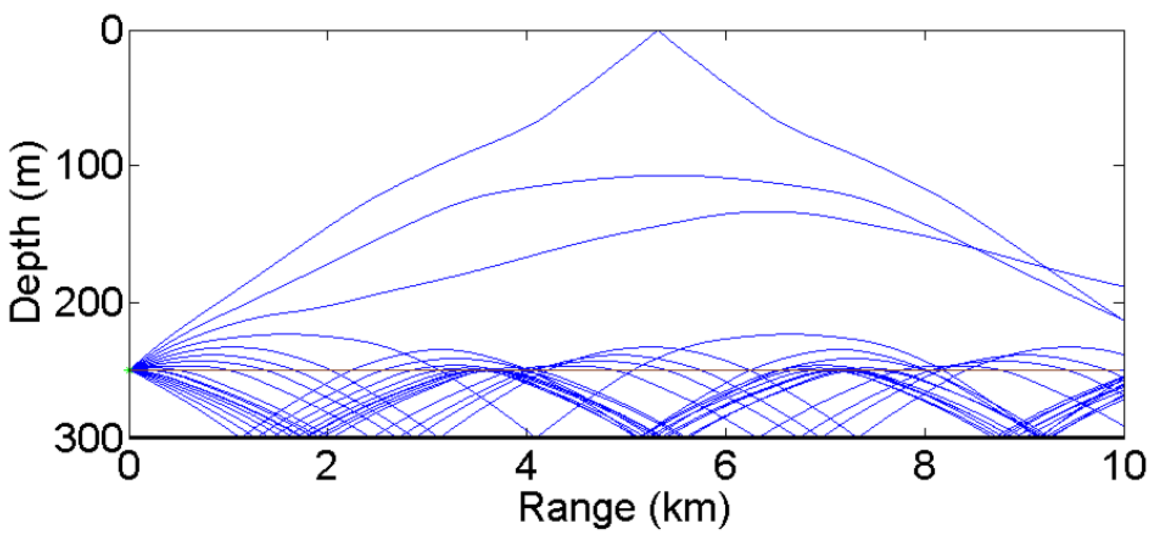


[2] Andrew Howard, "Multi-robot Simultaneous Localization and Mapping using Particle Filters," The International Journal of Robotics Research, vol. 25, pp. 1243-1256, December 01 2006.

Background
Acoustic Communications

- Water absorbs sound energy (reducing range).
- Sound reflects and refracts about horizontal barriers (fracturing signals).

Example Acoustic Transmission Paths [3]



[3] H Riksfjord, O T Haug, and J M Hovem, "Underwater Acoustic Networks - Survey on Communication Challenges with Transmission Simulations," in Sensor Technologies and Applications, 2009. SENSORCOMM '09. Third International Conference on, 2009, pp. 300-305.

Background
Acoustic Communications

- WHIO micromodems support several data rates, which increasingly trade off reliability for higher bandwidth.

WHOI Micromodem Data Rate Options [4]

Modem Rate	Modulation Type	Max Bytes per packet	Bandwidth (bps)
0	FSK	32	80
1	PSK	192	498
4	PSK	512	1301
5	PSK	2048	5388

[4] Acoustic Communications Group, “Micro-Modem Software Interface Guide," Woods Hole Oceanographic Institution, Woods Hole, MA, User Manual v3.21, Jan. 2013.

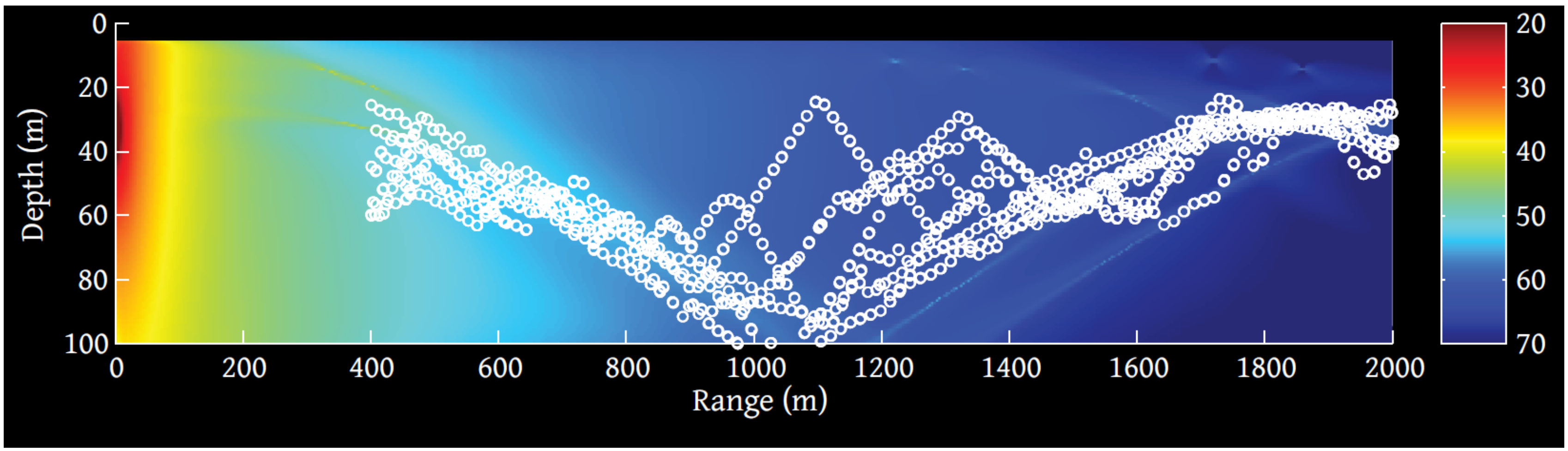
Background
Acoustic Communications

- Most collaborative AUV operations use conservative modem settings to ensure reliability (i.e. 80 bits per second with WHOI micromodem).
- The acoustic channel, while dynamic, can at times allow for higher bandwidth communications than currently used.
- Significant bandwidth increases could be obtained if the AUV adapted its behaviour based on the current channel state.
- Alternatively, AUV energy could be conserved by not transmitting if conditions make success unlikely.

Related Work
Schneider & Schmidt

- A model-based behaviour has been developed to adapt AUV depth online in order to maximize acoustic connectivity with remote source.

AUV Position (White Dots) Overlaid on Modeled Transmission Loss [5]



- This is accomplished by using online acoustic modelling (i.e. Bellhop) to estimate signal quality as a function of depth.

[5] T Schneider and H Schmidt, " Model-Based Adaptive Behavior Framework for Optimal Acoustic Communication and Sensing by Marine Robots," Oceanic Engineering, vol. 38, issue 3, pp. 522-533, July 2013.

Related Work
Schneider & Schmidt

- This approach is well suited to situations where the mission is not altitude-constrained.
- The objective in MCM operations is to map the seafloor, which requires constant-altitude flights to obtain consistent sidescan sonar data.
- Depth and path are determined by the search algorithms, and are not available to be modified to improve communications.
- The modem transmission settings *are* available to be adapted without impacting the MCM search operation.

Objectives

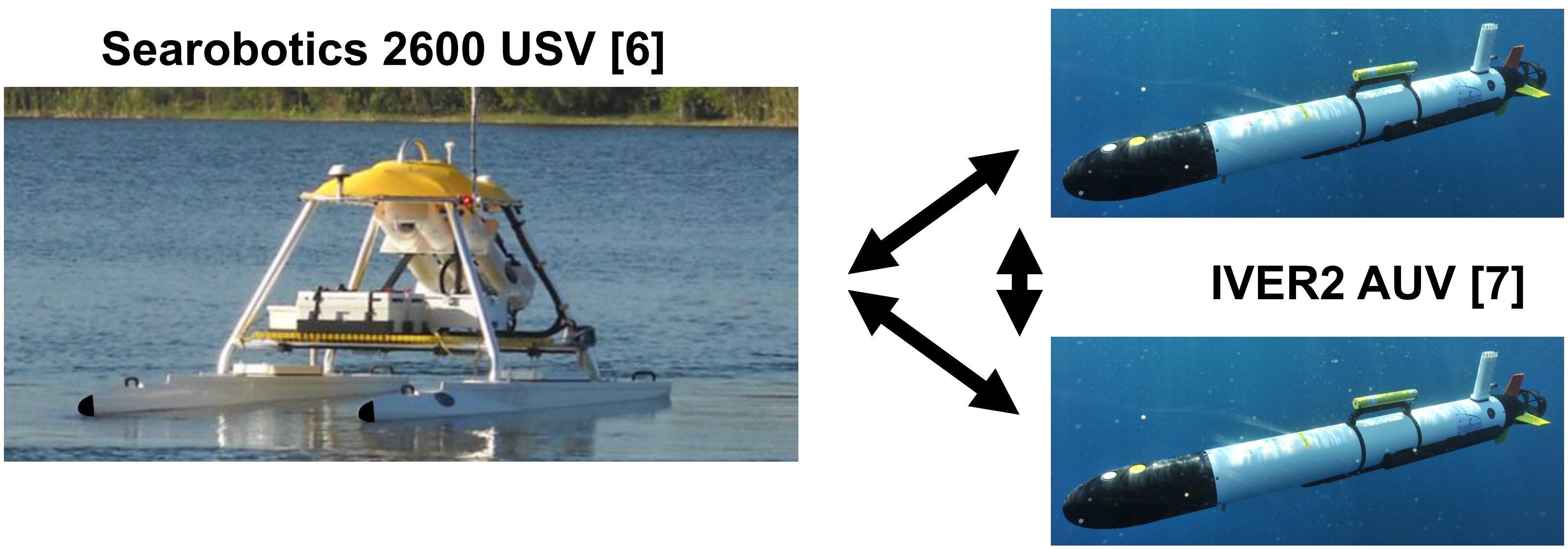
- Develop and test a behaviour-based AUV communications agent that adapts acoustic modem transmit rates online to achieve the highest reasonably reliable data rate given current conditions.
- If reliable communications are not probable given current conditions, transmissions should cease to save energy.

Testing

Experimental Equipment

- Hardware:
  - Two IVER2 AUVs
  - One Searobotics 2600 catamaran USV
  - All equipped with WHOI micromodem and PSK coprocessor

Searobotics 2600 USV [6]



IVER2 AUV [7]

[6] "User's Manual – DRDC USV-2600," Searobotics Corp., Palm Beach Gardens, FL, User Manual rev1.0, Mar. 2012

[7] OceanServer. (2013). *Photo Gallery*. Available: http://www.iver-auv.com/photogallery.html

Testing

Experimental Equipment

- Software:
  - Ubuntu Linux 10.04 LTS backseat PC
  - MOOS-IvP for payload autonomy
  - Goby2 communications suite for modem interface

Testing
Timeline

(1) Sea trials to gather test data

(2) Develop adaptive algorithms

(3) Sea trials to validate algorithms

Now *Fall 2013* *Winter 2014* *Spring 2014*

Testing
Preliminary Trials

- *Location:* Bedford Basin (~40m depth).
- *System setup:* Two-way communication between AUV and stationary modem.
- *AUV behaviour:* pre-programmed lawnmower patterns at a variety of depths, distances, and orientations as compared to the stationary modem.
- *Comms behaviour:* alternate messages between modems. Cycle through WHOI micromodem data rates, recording success rates as function of modem channel info, AUV position, and environmental conditions.

Adaptive Algorithm
Assumptions

- Assume that AUV does *not* have sound speed profile information.
- Algorithm must use the following inputs to estimate current channel capacity
  - Current fleet geometry
  - History of transmission successes & failures
  - History of modem channel estimation parameters

Adaptive Algorithm
To be determined

- How do the algorithm inputs correlate with acoustic channel capacity?
  - AUV fleet geometry variables (i.e. position, orientation, speed, etc)
  - AUV modem diagnostic outputs (i.e. ambient noise at receiver, received packet statistics, etc)

- What method(s) are best to control the adaptive behaviour?
  - Probabilistic algorithms
  - Reinforcement learning
  - Neural networks.

Questions?