Autonomous Underwater Exploration Using A Swarm of Mobile Sensor Nodes

Paul Bender
McNeese State University
Dept. of Mathematics, Computer Science, and Statistics
Box 92340
McNeese State University
Lake Charles, LA, 70609
pbender@mcneese.edu

Kay Kussmann
McNeese State University
Dept. of Mathematics, Computer Science, and Statistics
Box 92340
McNeese State University
Lake Charles, LA, 70609
kkussman@mcneese.edu

ABSTRACT
Underwater Sensor Networks are emerging applications for sensor network technologies. Many of the proposed applications for underwater sensor networks assume the sensor nodes will provide limited mobility capabilities of their own.

In this work we propose two related applications for an underwater sensor network consisting of a swarm of Autonomous Underwater Vehicles cooperating to explore underwater caverns archaeological sites.

Categories and Subject Descriptors
I.2.9 [Robotics]: Autonomous vehicles; J.2 [PHYSICAL SCIENCES AND ENGINEERING]: Archeology, Earth and atmospheric sciences, Engineering

General Terms
Underwater Sensor Networks, Robotic Systems

1. INTRODUCTION
Exploration of underwater shipwrecks and caverns can be an exciting adventure for Archaeologists, Geologists, and hobbyists. Currently, these adventures require a human to be directly involved in the exploration process.

Due to the extreme conditions, human exploration is impractical in many cases. Working time on the ocean floor is limited due to limited oxygen supply.

Shipwrecks and underwater caverns are also hazardous due to their maze like construction. Adding to the risks of sending a human underwater to explore such sites.

Remotely operated vehicles allow for increased time on the bottom, but they are limited in the distance they can travel from the vessel containing their operator by the length of the cable connecting them.

We propose a swarm of small Autonomous Underwater Vehicles (AUVs) can cooperatively explore shipwrecks and caverns without endangering human operators, and without the distance limitations of a cabled network.

2. RELATED WORKS
Existing literature has considered underwater sensor network nodes having limited movement capabilities [3, 2], the ability to drift [4, 6] or no movement capabilities at all [11]. For AUVs to explore an underwater shipwreck or cavern, motion control in 3 dimensions is required.

Additional attention has been paid to the limitations of traditional radio based wireless sensor network nodes in an aquatic environment [5]. An optical communication system provides an alternative communication path, but there are limitations due to line of sight issues [7]. Underwater acoustic networks provide the most practical networking physical layer for mobile underwater sensor nodes, though bandwidth is limited so care must be taken in retrieving data from the network [8, 9, 1, 12].
Figure 2: A Mock-Up of our small robotic submarines. This version is based on a design from the Robert Gordon University [10]

Figure 3: The motor assembly

Figure 4: Conceptual drawing of the audio based communication system

3. ROBOTIC NODES

Our proposed solution revolves around small robotic submarines with several independently designed subsystems. A description of each subsystem follows.

3.1 Chassis

The main body of our robotic sensor nodes is a small tubular frame constructed of PVC. The frame includes attachment points for motors, sensors, and watertight compartments for electrical components. The chassis will include a static buoyancy control device which will be adjusted when the mote is near the surface to have slightly positive buoyancy. Positive buoyancy will allow the sensor node to float to the surface in the event of a power failure.

3.2 Propulsion

The propulsion system consists of 3 electric motors each of which can be run in either forward or reverse. One motor is placed vertically in the frame to allow the robotic node to move vertically through the water.

3.3 Computational Control

The computational control system for our node is a Crossbow MicaZ mote. The mote will be the primary microcontroller on the sensor node. Its computational capabilities will be used for navigation, and collection of sensor data.

3.4 Sensors

Several sensors will be installed on the node for navigation and collection of data.

- Sonar devices will be installed so objects can be detected in 6 directions. This will aid in navigation and in surveying the site of interest. Touch sensors will augment the sonar system to allow the robotic node to feel its way around the site. These sensors will need to be tuned so they do not register a touch due to water pressure alone. Together, the sonar and touch sensors will allow the node to navigate through the confined spaces of a shipwreck or underwater cavern.

A Depth sensor will be installed. In addition to collecting data about depth, this instrument will prevent the sensor node from diving beyond the point at which the structure will fail.

- An electronic compass will allow the nodes to find their general bearing in the water. GPS is of limited use, so a compass is preferred.

Some or all nodes will be equipped with a video capture device. This device may be housed separately from the MicaZ mote and other control electronics.

3.5 Communication

The communication system will be an audio based system as seen in Figure 4. This communication system may share some components with the sonar sensors.

4. COOPERATIVE DATA COLLECTION

The AUVs will cooperate to collect data by using some nodes as beacons. In the case of an underwater shipwreck, beacons, which may be robotic nodes programmed to find the edge of the site, will be placed at the boundary points of the site under investigation. Mobile Nodes will sweep across the area defined by the beacons.

For interior exploration of a shipwreck, or for exploration of an underwater cavern, nodes will act as beacons at strategic points along the path the nodes take to descend into the cave. This will allow the deepest diving nodes to return to the surface with the data they have collected. The nodes
will need to communicate to decide which nodes should stay at the key points, and which nodes can continue to explore.

Data may be stored on each node until the node returns to the surface.

5. CONCLUSION
We have presented a high level design for a sensor network consisting of mobile nodes capable of exploring shipwrecks and underwater caverns.

6. REFERENCES