Current Progress in Building a Small Community of Simply Networked Micro-AUVs with Synthesis of Simple Behaviors Strategic and Research Directions

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Abstract

Ocean Robots LLC is developing a range of very low cost AUVs capable of repaid deployment in coastal waters. These vehicles can operate independently or in groups with the addition of simple behaviors and networking capabilities. Groups of small AUVs can expand various mission profiles and increase areas of operation while raising system performance through redundancy. Certain perimeter detection applications may only be possible with groups of vehicles. When groups of AUVs are deployed certain unique signaling and operational characteristics are conferred upon the system.

Introduction

Most AUVs are a result of research programs in which the vehicles are purpose built as platforms for a few sets of instrumentation or suite of software. As is traditional with ocean instrumentation, growth occurs in customized responses to user requirements. At present, an AUV costing $500K (USD) dollars is deemed relatively inexpensive (1). This level of cost inhibits both strategic and research deployments. With the large number of vehicles required for securing a large harbor, cost quickly becomes an issue. Similarly, the oceanographic research community is unlikely to entrust equipment of this value to the inexperienced for fieldwork. While numbers are increasing, there are probably less than one hundred AUVs ready for sea on any given day, worldwide.

Ocean Robots' family of vehicles makes maximum use of COTS (Commercial Off The Shelf) components and mass production techniques. The basic vehicles have a simple maneuvering capability and sensors for acoustic localization and signaling, optical signaling, and depth, as well as a magnetic compass.

While effort has been made to preserve the conventional methods of inter-AUV signaling by acoustic and optical means, a behaviorally based means of signaling is being investigated. This comprises a group behavior, in response to an obstacle or threat, which propagates across the group. This is in lieu of a conventional signal based on a release of energy. This technique may reduce the possibility of AUV detection.

The author has been positively influenced, as presumably many others have, by Braitenberg's book, "Vehicles: Experiments in Synthetic Psychology" (2). The intent with the simple vehicles described here, is to effect various tasks required for perimeter defense and oceanographic research by choosing limited but appropriate behaviors as opposed to pre-programmed, coordinate specific, missions.

In a perimeter or harbor detection and defense application, the use of ordnance against a target may be obviated because of proximity to the general population. In this situation a crowding or "hassling" behavior effected by a group of AUVs may be effective in forcing a target to surface or retreat.

Hull Components, no vanes, no propulsion

Vehicle Construction

At present, vehicles of two sizes are being constructed:

1. approximately 30cm length, 5cm diameter, and 650g weight in air

2. approximately 80cm length, 10cm diameter, and 5kg weight in air.

Hulls are constructed of polycarbonate tubing with PVC and acetal nosecones and tailcones. Passive stability in pitch and roll is achieved through appropriate placement of major payload components such as battery and electronics. Small amounts of ballast are added as necessary for static balance. The hull can easily accommodate additional instrumentation or increased battery size by using tubes of greater length and rebalancing. Power is provided by 6 VDC NiMH battery packs which supply a conventional brushed DC motor through a PWM controller.

Mechanical components are either COTS or setup to be produced on CNC machinery. The result is a hull (80cm) which can be produced for less than $400 (USD) and which is suitable for operation to at least 100m depth. Increased depth capability is a function of increased hull tubing wall thickness. With the CNC parts there is essentially no custom finishing. At present we are using extruded tubing for the hulls. The extruded tubing shows very slight eccentricity and occasionally requires some initial hand finishing

Conventional DC model servos are used in the larger (80cm) vehicle, while a smaller linear actuator, a current controlled solenoid is used in the smaller (30cm) vehicle.

The control electronics is comprised of PIC-type controllers implementing simple weighted loops. Sensor inputs to the controllers include:

1. magnetic heading from a PNI integrated 2-axis magnetometer (3)

2. depth from a Honeywell pressure sensor (4)

3. luminance information from a quad set of forward looking photo-transistors and associated buffer circuitry located in the nosecone

4. Phase and direction information from two sets of acoustic transducers located in the nosecone, which feed associated phase detection circuitry.

5. Simple "acoustic groping" for collision avoidance effected by driving the acoustic transducers and looking for close, <10msec returns

Capabilities

Both vehicles have the following capabilities:

1. Move forward at a speed of up to 3 knots

2. Go to a specific depth and maintain

3. Go to a specific magnetic heading and maintain; subset turn left, turn right

4. Sense a light source and home or avoid

5. Sense a sound source and home or avoid

6. Generate a light pulse detectable by other vehicles

7. Generate a sound pulse detectable by other vehicles

Group Signaling and Self Location

A school of swimming baitfish or a flock of birds in flight is a familiar sight to many. Often this type of group will continue with most members moving in unison until an obstacle or threat is detected. In response, the group will move in formation in a direction so as to avoid the threat or obstacle. Members of the group closest to the threat or obstacle will move in an appropriate avoiding direction. The next nearest members will follow the course change until it has propagated through the entire group. This is very much like aircraft flying in formation, in which each pilot follows a wingman. This phenomenon is referred to as self-location.

The conventional view of self location tends toward maintaining travel or some other beneficial behavior (5, 6). We believe that it can also be used as a kind of signaling which communicates a specific condition or target location. We term it group signaling.

A well-known example is the flocking of seagulls over schools of baitfish. Sport fishermen often follow the gulls because they seek the fish, which feed, on the baitfish.

In the initial phase of this project, various attempts were made to get the AUVs to swim in tight formation without external navigational beacons or extensive inter AUV signaling. Results were not encouraging, so an alternative behavioral solution was sought.

Let's say a harbor needs to be secured against underwater intrusions. A conventional response might be a large static SONAR or passive listening array. Alternatively, a few large AUVs with inertial navigation systems and acoustic modems might carry some SONAR or acoustic signature detection. At present price levels, this type of vehicle would probably cost several million dollars (USD) each. One quickly comes up against economics when considering how much area or coastline can be placed under watch.

An alternative is to deploy many simple micro-AUVs, which randomly cruise the harbor and exhibit simple observable behaviors upon detection of possible targets.

For example consider the following behaviors:

1. Cruise on fixed heading at random depth until depth of less than 2m or an obstacle is encountered.

2. If depth < 2m or obstacle, then surface and flash a light

3. Reverse course or choose another heading

4. Loop to #1.

In a typical harbor with occasional construction or obstruction the AUVs may surface in response, based on behavior #1. Since the obstruction is static however, the pattern of surfacing AUVs should be relatively constant with AUVs coming up where there are obstructions or certainly as the confines of the harbor are reached. During the day, brightly colored vehicles should be directly observable. Alternatively, the vehicle can take a GPS fix upon surfacing and RF transmits it to a central database for collection. If there is a significant change in this pattern, then additional assets can be involved in order to determine the nature of the target.

The sophistication of the behaviors and the number of sensors can easily be increased at marginal cost as experience with this type of system grows.

This type of system is counter-intuitive, as it does not rely on high levels of stored data precision nor on large, expensive, and complicated vehicles. A somewhat homespun analogy is that sometimes a tripwire with a bell attached can be more effective than several radars.

This type of system can be quickly deployed for long periods in conjunction with an AUP (autonomous underwater platform), such as the one built at the University of Massachusetts, SMAST (7), acting as a recharging station.

Research Applications

The author has noticed that many sets of "most recent" oceanographic data are quite old. In some instances, the most recent data are over ten years old. This reflects the cost of obtaining data and taking many stations in a conventional oceanographic cruise. One way to improve this situation is by deploying large numbers of AUVs as mobile data samplers/recorders within the water column. Given the relatively slow movement, which would be typical, a surface or AUP-based system could keep a GPS referenced log of position while determining the micro-AUV positions at useful intervals with an LBL or SSBL system. The time-stamped micro-AUV data stores could then be off-loaded and the raw data entered into an appropriate database. In the event that interesting data can be identified as such by a single AUV, neighbor AUVs can be called by pinging or flashing to enrich the data.

Hassling Targets and Networking

In populated areas the use of force against a target must be carefully controlled. Small moving submerged targets are intrinsically hard to identify and categorize. In colloquial terms the question becomes, "Is it a fish or a bad guy"? With all the divers and swimmers in coastal waters it becomes desirable to directly observe the target before any further action is taken.

It has been observed (8) that dolphins will attack Tiger sharks by butting with their rostrums and slapping with their tails.

Although this has not yet been tried, we suggest that a similar AUV-based protocol be followed with targets in areas deemed secure. Specifically, implement the following networking behavior:

1. AUV swims toward target, which it has detected or to which it has been directed by another system. Measure depth.
2. AUV swims into target, striking it, then withdraws.
3. Signal others that a target has been contacted by pinging or light pulsing.
4. Other vehicles converge
5. Target depth is measured again.
6. If target is moving toward surface, then standoff.
7. If target depth remains constant go to #2.

Current Status

At present both hull types are being completed. Production costs are in line with the estimates mentioned previously.

The control electronics has been completed and has been statically tested in water. The sensors have been deployed in water and have performed properly with simulated targets carrying sound and visible light sources.

To the extent possible, the first mission scenario has been physically simulated at the dock.

Final integration has begun and it is hoped that by time of presentation additional data will be presented.

This work is a part of on-going development at Ocean Robots. The reader is invited to get updated information posted at frequent intervals:

www.oceanrobots.net

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