Autonomous Vehicles for Remote Sample Collection in Difficult Conditions

Enabling Remote Sample Collection by Non-(robotic) Specialists

Researchers: Shivali Chandra, Devynn Diggins, Silas Hughes, Liani Lye, Victoria Preston, Matthew Rush, Mindy Tieu, Jay Woo, Adela Wee
Advisors: Andrew Bennett, Iain Kerr

Introduction

Despite more recent advances in technology and oceanography, very little research has been focused on the general health of the ocean, whose state affects the whole globe. Specific species of whales, such as sperm whales, are apex predators, and therefore accumulate greater concentrations of various pollutants from throughout the water column through feeding activity. By taking a whale blow sample, scientists can run analyses to detect traces of pollutants, hormones, and DNA to determine health of the whale, and health of the oceans and our globe.

Sample collection currently relies on a human; manned boats and low-flying planes inadvertently disrupt the subject's usual behavior. By designing an intelligent robot to conduct reconnaissance, scientists will be able to rapidly collect data from hundreds of meters away safely and without stressing the subject. SnotBot allows for sample collection in previously inaccessible locations and during rare, short-duration events like whale surfacing for breathing. Before applying this method to protected whales, Olin College and Ocean Alliance simulated the anticipated interaction with a mechanical whale analogue equipped with sensors in the Gulf of Mexico in the summer of 2014 in order to create a baseline dataset of what the whale experiences.

SnotBot will be a fully autonomous, user-friendly research platform that can be used robustly in the field to survey impossible or inconveinent locations during events of interest.

In order to meet this goal, SnotBot must be able to:
- Take off of a research vessel autonomously
- Navigate based upon GPS and localization techniques to a subject of interest autonomously
- Identify and hover over a subject of interest
- Collect a sample
- Return to the mission vessel autonomously and land
- Have a simple human interface to the hardware and software for diagnosis, attaching sampling equipment, watching the mission execute

Hardware Systems

Vehicles

We currently have three quadcopters and two hexacopters. Four of the vehicles (all the quadcoptors and one hexacopter) run with Pixhawks and operate using ROS and Python. The other hexacopter is run on DJI and interfaces with a Lightbridge to stream HD video from a GoPro Hero 3+ Camera. Three of the vehicles (all the quadcopters) are waterproofed. Basic waterproofing allows us to conduct water landings while sustaining minimal damage. The only exposed portion of our copters are the propellor motors.

SnotShot

SnotShot is an artificial whaleblow generator and sensor platform that acts as a surrogate such that we can practice collecting whale condensate from a safe distance while measuring the physical effects of a multirotor hovering over a whale. It is a series of pressurized PVC pipes outfitted with an ultrasonic rangefinder that senses the presence of an object up to nine feet above the system. Sufficiently close objects will trigger the release of a sprinkler valve on the PVC pipes that releases the air into a small "condensate" (typicallly dyed fresh water) reservoir and then out of a nozzle the top of the system. The result is a cloud of water droplets that simulate a whale's blow. Preliminary tests on the Gulf of Mexico and Gloucester Harbor have shown that we were able to fly close enough to the "whale" to trigger the sensor and collect artificial whale condensate.

[Clockwise from Top] 1) Our fleet of SnotBots - 2 hexacopters and 3 quadcopters. The hexacopter towards the center of the image is outfitted with the DJI Naza M, while all other vehicles have been built with the Pixhawk. 2) SnotShot, our whale surrogate, was used to simulate a whale coming to the surface of the water to release its blow. Equipped with an altitude sesnor, hydrophone and anemometers, it is also our data collection platform. 3) Testing with two of the fleet and SnotShot in Gloucester Harbor.

Software Systems

The Pixhawk in conjunction with QGrundControl is an open-source autopilot system. We will use this system as a communications layer between our code and this autopilot system.

When in manual control mode, the robot brain can be remotely monitored through QGroundControl, an open-source resource for flying quadcopters and hobby planes that use serial/radio links, the Pixhawk systems, or wifi networks. The system also has built-in autopilot system, which we will atttempt to interface to via Willow Garage's Robot Operating System (ROS).

There will be a communications layer to which we interface our own code - this communications layer is QGroundControl. We are building a finite state control loop via ROS that will read in sensor data, make decisions, map locations, and perform the missions. There will be a vision system on the robot which will be one of the major sensory components. Using OpenCV, image and video processing in the real world may lead to a sophisticated SLAM system and 'whale-locator' which will ultimately lead to an efficient platform for performing tasks.

Data Collection Methods

Before deploying SnotBot in the real world, it is necessary to determine how the drone may affect the whale as it hovers in the air over the subject. To measure this, we constructed our whale blow simulator, SnotShot and equipped it with multiple hydrophones and anemometers to measure the sound and downwash on our simulated whale.

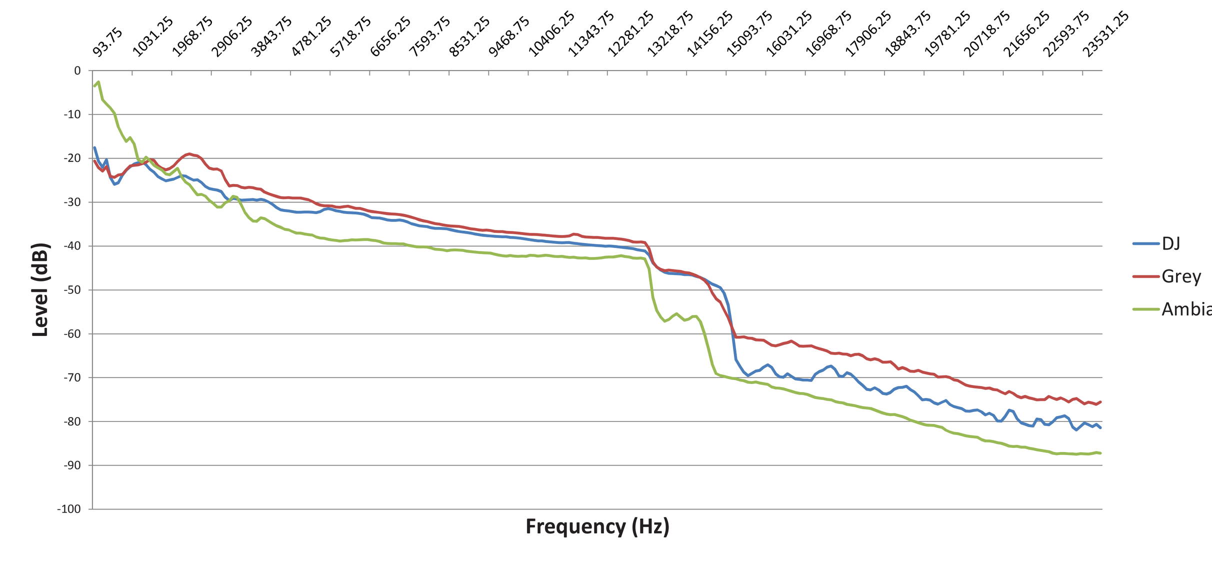
In order to simulate the most realistic environment, we traveled to the Gulf of Mexico and deployed our whale surrogate SnotShot into the ocean. We then flew our SnotBots approximately 5 to 10 feet above the whale surrogate, to which we attached two anemometers at right angles to each other so that we could measure the velocity of the downdraft caused by the quadcopters' propellers. In addition to anemometers, we attached two hydrophones to SnotShot - one hydrophone collected data at 2 feet below the surfce of the water and the other collected at 10 feet. As a result, we were able to hear what both a small and large whale might perceive while surfacing.

Our gray SnotBot flying over SnotShot, which sprays fake whale snot into the air, during testing in the Gulf of Mexico, Summer 2014

Preliminary Results

After processing the hydrophone and anemometer data collected on the trip to the Gulf of Mexico, we formed useful preliminary results. About an hour of ambient audio was collected in testing. Of this, approximately 20 minutes were filled with quadcopter testing. Preliminary results indicate that our particular quadcopters generate a band of frequency in the 14kHz range that typically is not as loud as other acoustic signals typically found in the ocean.

With this in mind, it is important to note that available research on the hearing ranges of whales indicates that the frequency produced is not within their sensitivity ranges, nor at a volume level which is recognized to be noticed by whales. This is an exciting result, as it is one piece of evidence that supports our current design and contributes to our library of experiments that will be submitted to the National Marine Fisheries Seerfice for licensing.



The results from the hydrophone testing. Both the blue and red lines indicate a small peak in the 14kHz range, which indicates that the SnotBots are making noise at a frequency typically silent. studies of whales have led us to conlcude that this amount of change in the frequency band is effectively negligable.

Conclusion and Future Work

While much work has been accomplished to date, we are constantly working to improve upon our current prototypes. Future tasks we would like to accomplish include:
- Recreating our current SnotBot copter design to be more user-friendly regarding assembly and accessibility
- Redesigning SnotShot to be more responsive and robust, in order to increase accuracy and efficiency
- Developing our code to the point where SnotBot is able to function without the aid of a specialist human operator
- Creating a landing platform that can protect, charge, and store collected data from SnotBot
- Integrating our vision system with a DJI Lightbridge, capable of 1080p video at 30Hz, and moving all the copters to open-source autopilot systems
- Streaming video from the aerial vehicles
- Addressing and solving the issue of a short battery span

Once we are able to achieve these goals, the possibilities of what SnotBot can accomplish are endless. From aiding military research to gaining information about wildfires, and even to collecting samples of lava, we aim to create a fully autonomous and multi-functional copter that has potential in countless fields of research.

[Left] Our team of researchers and advisors at Gloucester Harbor Paint Factory.

[Below] The team of researchers from Ocean Alliance and Olin College in the Gulf of Mexico.

A Partnership Between: Ocean Alliance (www.whale.org), Olin College of Engineering, Olin Intelligent Vehicles Lab

Curious? Comments?
Please contact:
Andrew.Bennett@olin.edu
Victoria.Preston@students.olin.edu