The Detection and Tracking of Anthropogenic Acoustic Sources Utilizing a Hybrid Autonomous Underwater & Surface Vehicle (AUSV)

(Detecting, Locating and Tracking Anthropogenic Acoustic Targets)

Neil Trenaman, Ocean Aero, Inc., ntrenaman@oceaenaero.us

INTRODUCTION:

The automated detection and classification of maritime traffic is a challenging problem and is of great importance to many organizations. For maritime domain awareness an automated boat detection system could alert authorities of potential illegal or immanent national security threats by unidentified vessel traffic. However, not all vessel traffic and recreational or small boats, for example commercial snorkeling and diving boats would be considered as a threat. For this reason, a classification system is needed to discriminate these different types of boats. The need for similar systems arises in the monitoring of harbor traffic for national security. There are many different methods for boat detection, examples including radar, electro-optic (EO) and infrared (IR) cameras, and both active and passive sonar. Active sonar and radar provide little additional information beyond detection. Radar and optical methods are limited by line of sight for detection, and optical systems can be obscured by rain, fog, or may require daylight. Active sonar can be used or detection of quiet targets, but the high level of reverberation in shallow water environments often causes many false detections, which limits its utility.

As an alternative, passive sonar has been proven to be an efficient tool for the detection and identification of self-emitting targets. There is significantly more work to be done the on the classification of the acoustic signature(s) of small boats (1).

Detection and extraction of underwater acoustic signals play an extremely important role in marine vehicle tracking and is one of the key technologies in underwater source detection, location, tracking, recognition and as well as acoustic communication. Energy detection, feature detection and matched filter detection are commonly used range from high detection performance to low computation complexity, which can usually work well to some extent. Among these researches of the underwater passive detection methods, energy detection is mostly discussed and used in practical for its merits of lowest computational cost and easy to realize, while shows a poor performance under low SNR marine environment. However, over the past several decades, the marine environment has been more complexed in both natural and anthropogenic influences that ambient noise revealed. And as a consequence, the existing underwater passive detection methods are facing serious challenges, for which advanced detection scheme with better performance is still worthy investigating, especially under low signal-to-noise ratio (SNR) region (2).

SOUND IN THE OCEAN

Anthropogenic sound is created in the ocean both purposefully and unintentionally. The result is noise pollution that is high-intensity and acute, as well as lower-level and chronic. The locations of noise pollution are along well-traveled paths in the sea and particularly encompass coastal and continental shelf waters. Increased use of the sea for commercial shipping, geophysical exploration, and advanced warfare has resulted in a higher level of noise pollution over the past few decades.

NATURAL SOUND SOURCES IN THE OCEAN

The ambient acoustic environment of the ocean is highly variable. At a given time and place, a broad range of sources may be combined. In addition, conditions at a particular location may affect how well ambient sounds are received (e.g., sound propagation, water depth, bathymetry, and depth). Natural phenomena known to contribute to oceanic ambient noise include: (a) wind, sea state and swell patterns, (b) bubble distributions, (c) currents and turbulence, (d) seismic activity, (e) precipitation, (f) ice cover and activity, and (g) marine life.

ANTHROPOGENIC SOUND SOURCES IN THE OCEAN

Human activity in the marine environment is an important component of the total oceanic acoustic background. Sound is used both as a tool for probing the ocean and as a byproduct of other activities. Anthropogenic noise sources vary in space and time, but may be grouped into general categories: (a) large commercial ships, (b) air guns and other seismic exploration devices, (c) military sonars, (d) ship-mounted sonars, (e) pingers, (f) acoustic harassment devices (AHDs), (g) polar ice-breakers, (h) offshore drilling implements, (i) research sound sources, and (j) small ships (3).

NEED FOR DETECTION:

The global threat of illegal or unfriendly foreign incursions into sovereign national martime domains is a growing concern for border security and national defense agencies. Those agencies tasked with the detection, identification and tracking of these threats are generally under resourced to deal with the increase in events both in the spatial and temporal coverages needed to provide a comprehensive deterrent and early warning response.

Passive acoustic systems are the most promising sensor technology available to fill several gaps in maritime domain awareness. They offer the ability to detect, track and classify any vessel generating noise on, or under the water. One of the largest sensor gaps for maritime law enforcement is the inability to monitor small low visibility boats or small vessels not reliably detected by radar, nor are they required to transmit Automatic Identification System (AIS) messages.

TEHCNOLOGY PLATFORM – OCEAN AERO AUSV

Ocean Aero has developed an environmentally powered autonomous marine vehicle that has the unique ability to operate as both an Autonomous Surface Vehicle (ASV) and an Autonomous Underwater Vehicle (AUV) resulting in a hybrid, dual-modality Autonomous Underwater and Surface Vehicle (AUSV) that offers a single platform that can self-deploy to a remote operational area and dive underwater to perform a variety of mission or simply avoid detection. The AUSV uses two modes of propulsion on the surface. The primary mode is wind power. The vehicle uses a two-element rigid wing (similar to an airplane) to efficiently sail at speeds over 5 knots. The wing and flap are controlled by the CPU using environmental data from an anemometer, an ultrasonic boat speed sensor, an IMU (inertial measurement unit) and a GNSS antenna. Based on the mission parameters, the vehicle uses proprietary algorithms to determine the fastest approach to target waypoints. This mode of propulsion uses very little power and with the solar panels recharging the batteries, the AUSV can operate for extended period of time at sea.

The second mode of propulsion is thruster power. The AUSV uses a SeaBotix thruster to motor at speeds over 2 knots. This capability is useful for low wind conditions, launching and recovering the AUSV from a ship or pier, and flooding the vehicle for quick dives. The flooding feature is due to the thruster's innovative rotating mount. While sailing, the thruster is stored inside the hull to reduce drag. It rotates outside the hull for motoring and can be positioned at 90 degrees to the hull for rapidly flooding or dewatering the vehicle.

For operations on the surface, the user can remotely create, upload and execute missions using a web-browser interface and satellite communications. The mission control dashboard uses waypoints to define operational parameters (sailing, motoring, station keeping, diving, decks-awash loitering, etc.) and user-defined zones to restrict operations.

Underwater, the AUSV 'Navigator' model can dive to 200 meters using a robust ballast system similar to a submarine. The system can navigate underwater using predefined missions and use two thrusters to achieve speeds over 2 knots.

For command and control, the AUSV uses Satellite and Wi-Fi radios for communications and optional 900 MHz and cellular antennas for expanded capabilities.

Utilizing a hybrid autonomous underwater & surface vehicle (AUSV) developed by Ocean Aero, Inc. initial tests and evaluation for a three-dimensional passive acoustic hydrophone array coupled with on-board real-time processing for the detection, tracking and reporting of anthropogenic acoustic targets will be illustrated. Ocean Aero AUSVs equipped to detect, recognize and track particular classes of surface or subsurface vessels that are deemed to be of high interest as potential threats to maritime border security is discussed.

SENSOR TECHNOLOGY

The Ocean Aero AUSV was equipped with a custom designed three dimensional passive acoustic array consisting of twelve hydrophones spaced in a cluster and located underneath the AUSV hull (Figures 1& 2).

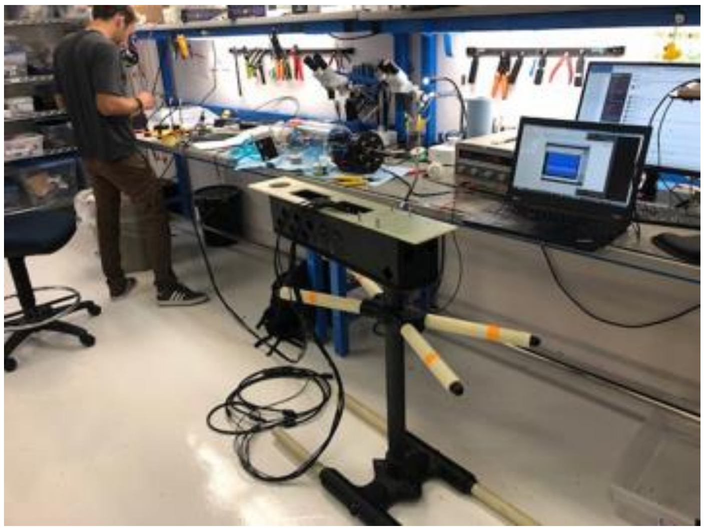

Figure 1: The 3-D multi-hydrophone array during bench tests

Figure 2: The 3-D multi-hydrophone array during in-water testing

FIELD TRIALS

Results of initial sea-trials are very promising and the graphical display of the target of interest from initial detection to tracking in real time are presented below.

With reference to the target frequency of 500Hz indicates that the type of vessel of interest would be smaller than a 12m fishing vessel traveling at a speed of 7 knots.

FIELD TEST CRITERIA:

- Preliminary Goal: AUSV shall have a Hydrophone array capable of detecting other sea vessels within 5 nautical miles generating acoustic signatures above 500 Hz.
- Verification: Visual, RADAR & AIS
- Test Equipment: AUSV, GPS, 3-D Passive Acoustic Hydrophone array and signal processing computer, support boat and target boat.
- Expected Result: Identify target signature with an acoustic signature above 500Hz.
- Confirm range to target, bearing and compute latitude and longitude position.
- Track the identified target and update range, bearing and new latitude and longitude position.

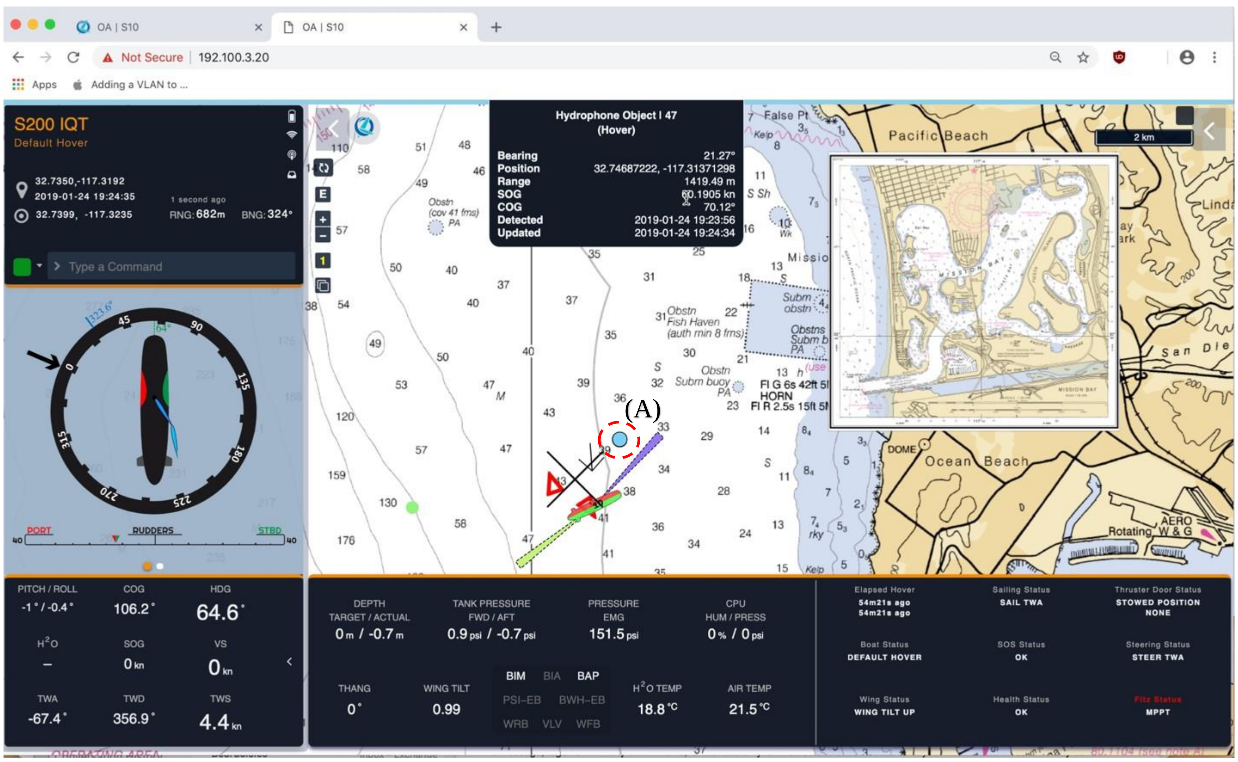

Figure 3. Location of at-sea trial showing the position of the AUSV, nearby AIS targets and the initial detection of the 500Hz target of interest (A)

The passive acoustic array initially detected the target boat and after a continuous set of sixteen positive returns, the target boat's latitude and longitude position was confirmed and continually updated as the target boat moved through the detection area.

The sequence of depicted in Figures 4a,b,c indicates the initial detection and location of the target of interest denoted by the marker( ) at point A (Figure 4a) and the progress of the target as it transected to point B (Figure 4b) and then point C (Figure 4c).

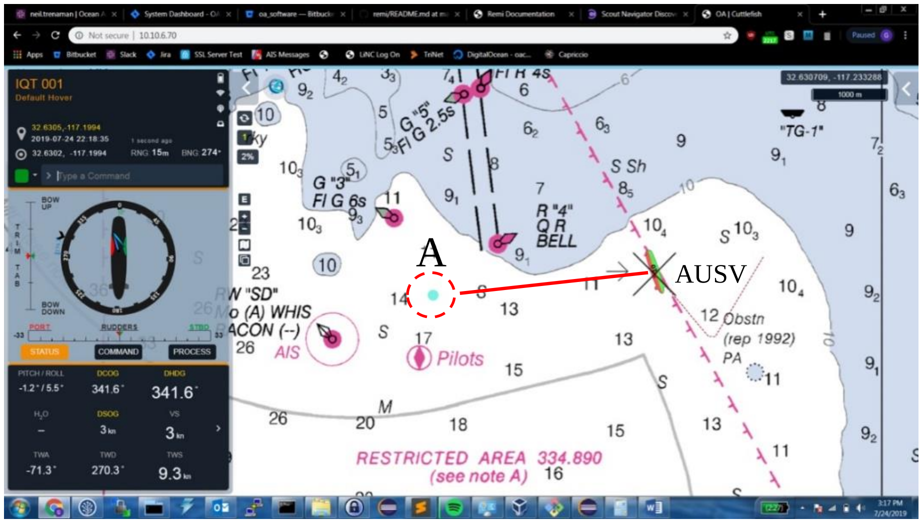

Figure 4a: Target (A) detected and Lat Long position confirmed

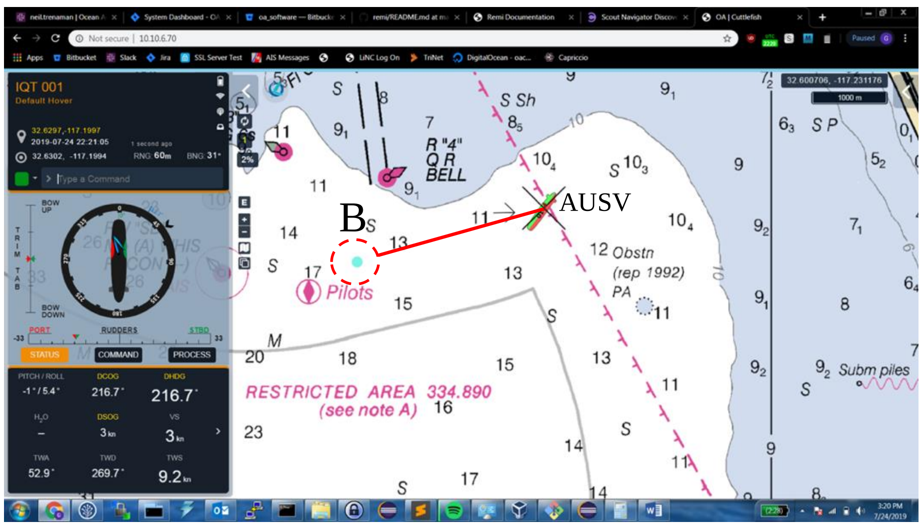

Figure 4b: Tracking Target (B) as it moves away from the initial detection position

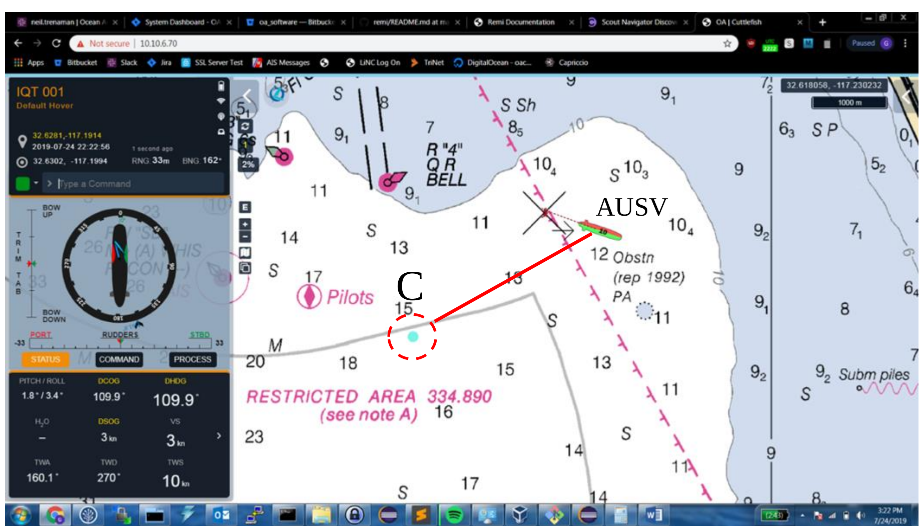

Figure 4c: Tracking Target (C) as it continues to move away from the initial detection position

CONCLUSION

The Ocean Aero AUSV equipped with a three-dimensional passive acoustic hydrophone array successfully demonstrated the feasibility of using an autonomous underwater and surface vehicle (AUSV) for the detecting, locating and tracking of anthropogenic acoustic targets in a pre-specified acoustic frequency range, which for this test was >500Hz.

The following goals were achieved :

1. AUSV equipped with a Hydrophone array capable of detecting other sea vessels within 5 nautical miles generating acoustic signatures above 500 Hz.
2. Verification via visual, RADAR & AIS methods were realized
3. Identify target signature with an acoustic signature above 500Hz.
4. Confirming range to target, bearing and computing latitude and longitude position.
5. Tracking the identified target and updating range, bearing and new latitude and longitude position.

Further test and evaluation in a wider range of ocean environments is a desirable next step as well as assessing options for integrating the hydrophone array directly into the hull of the AUSV or alternatively having the hydrophones imbedded in a thin line towed array.

References:

1. Ogden, GL., Zurk, LM., Jones., ME. Peterson, ME. 2011. Extraction of small boat harmonic signatures from passive sonar. The Journal of the Acoustical Society of America 129, 3768 [DOI: 10.1121/1.3583500]

2. Dahai Cheng, Huigang Xu and Ruiliang Gong, Huan Huang, 2018. Ships Matching Based on an adaptive acoustic spectrum signature detection algorithm. Signal & Image Processing : An International Journal (SIPIJ) Vol.9, No.4, August 2018

3.Hildebrand, JA. 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology-Progress Series. 395:5-20.