Research Note

AUV Design And Development To Validate Low Ambient Frequency Noise

Aruneema Deshmukh, Dr (Cdr) Arnab Das

BACKGROUND

An autonomous underwater vehicle, or AUV, is a self-propelled, unmanned, untethered underwater vehicle capable of carrying out simple activities with little or no human supervision. AUVs are often used as survey platforms to map the seafloor or characterize physical, chemical, or biological properties of the water.[1]

The first AUV was developed at the Applied Physics Laboratory at the University of Washington as early as 1957 by Stan Murphy, Bob Francois and later on, Terry Ewart. The "Special Purpose Underwater Research Vehicle", or SPURV, was used to study diffusion, acoustic transmission, and submarine wakes.Acoustic signals from the accompanying research vessel guided SPURV in moving below the surface of the water. SPURV then generated models of underwater physical properties such as ocean currents and temperature.[2]

AUVs are attractive options for ocean-based research.

- They can reach shallower water than boats can and deeper water than human divers or many tethered vehicles can.
- Once deployed and underwater, AUVs are safe from bad weather and can stay underwater for extended periods of time.
- They are also scalable, or modular, meaning that scientists can choose which sensors to attach to them depending on their research objectives.
- AUVs are also less expensive than research vessels, but they can complete identical repeat surveys of an area.[3]

LOW FREQUENCY AMBIENT NOISE

Although sound emanates in the ocean from a myriad of sources, shipping has become a dominant source of low frequency ambient noise in the ocean and thus mapping the noise created by the ships becomes important both for defence and marine conservation purposes.[4] Over the years, the shipping noise estimation techniques as well as the applications have evolved quite a bit with advancement in technology and now have relevance to multiple military and non-military applications across multiple stakeholders.[5]

Underwater ambient noise in shallow-water areas of the tropical zone of the Indian Ocean is characterized by higher level spectral maxima, which distinguish this type of noise from the noise in the deep-water ocean.[6]To study Underwater Ambient noise variability from satellite data in Indian Ocean, data available for noise sources such AIS (Automatic Identification System) traffic data, wind (ASCAT) and rain (INSAT-3D) information from satellite observations was considered.[7]

The use of a moving array - such a line array towed behind a moving AUV - provides distinct advantages
for the measurement of the ambient noise field. Using both simulation and experimental data, this iterative noise field measurement technique can provide a continuously updating calculation of the local ambient noise field, including accounting for moving targets.[8]The marriage of AUVs and lightweight towed arrays is a natural progression in the

development of littoral autonomous sensing networks for applications such Anti-Submarine Warfare, marine mammals or ambient noise measurements.[9]

AUV COMPONENTS & SYSTEMS

Every AUV at its most basic form must have some sort of navigation system, propulsion system and a dry, watertight environment to house onboard components. In addition, an AUV will usually possess the following systems and components as seen in Figure 1. [10]

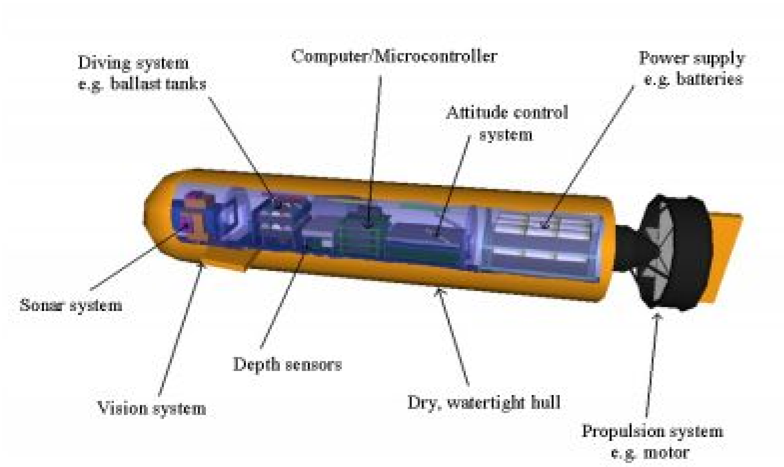

FIGURE 1. : AUV systems and components.

PAYLOADS-SENSORS FOR NOISE MEASUREMENT

Autonomous recorders for use in measuring underwater sound are now increasingly available commercially. Such recorders consist of a hydrophone connected to an electronics pod containing amplifier, ADC, data storage media and batteries to power the unit. These devices have greatly increased the capability for ocean noise measurement without the need for bespoke designs that require great expertise to set up and operate.[11]

The smaller size of these new vehicles compared to AUV platforms typically used for ocean exploration also makes deployment and operations possible in accessible smaller bodies of water such as lakes and rivers.However, the limited payload space and power availability of these platforms constrains the types of sensors that may be installed, demanding a compromise between operating range, mission duration, and sensor use.[12]

ACOUSTIC MEASUREMENTS DONE BY AUVS

The use of autonomous recorders is motivated by the need to monitor underwater noise, such as in response to the requirements of the European Union Marine Strategy Framework Directive. The performance of these systems is a crucial factor governing the quality of the measured data, providing traceability for future underwater noise-monitoring programs.[13]

Deployment tests of a prototype hydrophone array showed that a small diameter, low noise, AUV towed array is achievable. Further, the AUV was able to tow the array at speeds of about 2-3 knots in a stable configuration. The excellent coherent beamforming results observed in the small Dodge Pond clearly show that this system is a feasible and valuable acoustic measurement tool.[14]

The central element of Underwater Vehicle Networks for Acoustic and Oceanographic Measurements in the Littoral Ocean program is a prototype underwater vehicle network managed remotely by a surface platform, including moored sources and arrays, AUVs equipped with a variety of acoustic and environmental sensors, and reliable navigation and communication system. [15]

AUVS IN INDIAN OCEAN REGION

For the past few years, the Defence Research and Development Organisation (DRDO) has been designing and developing multiple AUVs to meet broader operational requirements for futuristic scenarios developed an autonomous underwater prototype for multiple maritime missions in India's waters. Manohar Parrikar, the defence minister, announced in the Parliament that a feasibility study undertaken for the development of different types of AUV platforms showed that the DRDO was capable of designing various kinds of UUVs from hand-held slow-speed ones, to military-class platforms, 22 with the capability to assist in the entire gamut of maritime security. The DRDO's prototype is a four-metre long, 1.4-metre wide, flat fish-shaped vehicle which can travel at a speed of about seven km per hour at depths of up to 300 metres below sea level. Fully pre-programmed in terms of algorithms and mission requirements, the robotic vehicle is piloted by an on-board computer that employs technologies developed by the Visakhapatnam-based Naval Science and 23 Technology Laboratory (NSTL). Reportedly, the design is being reworked to provide the prototype with passive sonar and electro-optical sensors for anti mining missions.
India has the 'Samudra', a 'low cost' AUV that operates underwater with pre-programmed inputs. Fitted with an on-board image processing unit, it can undertake 'path detection, obstacle avoidance and target identification' under the sea.[16]

CHALLENGES

Given the specifications (operating range,endurance, and sensor use.) :-Design Challenges of AUV

- Optimization (Power,Cost)
- Total Payload Calculation
- Testing of AUV
- Collision Avoidance (path)
- Monitoring the position of AUV
- Procedure incase of Failure (overheating, water seepage etc)

Challenges in accurate noise measurement

Calibration: The recorder should be supplied with a full system calibration including all information required to determine the absolute levels of the measured data (including hydrophone calibration, amplifier gains, ADC scale factors, etc). An in-situ calibration check with a hydrophone calibrator (pistonphone) is strongly recommended before and after deployment. This will cause a signal of Good Practice Guide for Underwater Noise Measurement 29 known sound pressure level to be recorded within the stored data file, and will provide valuable information on the system performance (at least at one frequency).
Self-noise: For measurement of low amplitude signals, the system self-noise is a key parameter and this information should be requested from the supplier. High self-noise can originate from poor choice of hydrophone and amplifiers, or from pick-up of electrical noise generated by the electronics and data storage system (the latter can sometimes generate electrical spikes which are recorded as spurious signals). The electronics pod can also display resonance behaviour at very low frequencies, and this can affect the overall sensitivity if the hydrophone is connected rigidly to the recorder pod.

Influence of recorder body (and guard): The proximity of the hydrophone to the body of the recorder unit (which is usually an air-filled case containing the batteries and electronics) can give rise to problems from reflected signals scattered from the recorder body being picked up by the hydrophone. The effect of this will be to cause fluctuations in the frequency response of the system at kilohertz frequencies (for the sizes of typical recorders, the effect is much reduced at lower frequencies), and fluctuations in the directivity of the receiver. A full free-field calibration can be used to characterise the effects, but a better solution would be to deploy the hydrophone on a short cable so that it is not positioned adjacent to the recorder body. Some hydrophones are fitted with a protective guard in the form of a metal cage, which reduces the chances of damage to the hydrophone element. Although this protection is desirable, a poorly designed guard can influence the frequency response and directivity at kilohertz frequencies, and it is advisable to calibrate the hydrophone with the guard in place to determine the degree of influence.

Dynamic range: The dynamic range of the system is particularly important when measuring high amplitude sounds, and this information must be specified by the supplier so that the maximum undistorted signal level can be estimated, and any saturated signals eliminated during analysis of the data. With autonomous recorders, there is typically no opportunity to alter the systems settings (for example gain settings) after deployments, and therefore it is necessary to make an estimate of the maximum signal likely to be encountered during the deployment.[11]

Challenges which are faced in IOR

Littoral waters:Tropical littoral environment represents its unique challenges due to spatio-temporal variation of ambient noise with colored spectra and non-Gaussian statistics.[17] The tropical littoral waters in the Indian Ocean Region (IOR) presents sub-optimal performance of the sonars being deployed for any underwater efforts.[18]

Characteristics of Littoral Waters:

- shallow water depth
- difficult acoustical conditions
- high density of sonar contacts
- military platforms particularly silent
- danger of collisions with obstacles and sea floor impacts [19]

RESEARCH DIRECTIONS

AUV design,development & deployment

Modular & Scalable AUV: Modular AUV are designed so that they can be adapted to carry a range of payloads and scalable to ensure it can be adapted to suit the end users' mission.[20]

Data Collection

Underwater Acoustic Recorders: The ambient sound field in the ocean is a combination of natural and manmade sounds. Consequently, the interpretation of the ambient sound field can be used to quantify these processes.[21]

Data Analytics

An analysis technique is described that permits the classification of ambient noise sources (wind generated and shipping) without the need for information concerning the environment or shipping in the area of interest. Wind‑generated and ship‑generated ambient noise, or a combination of the two, can be classified by finding the zero‑axis crossing time of the autocorrelation function versus frequency of the long‑term (greater than two weeks) ambient noise time series for a given geographic area.[22]

How to verify the estimation

Spatio-temporal mapping of the noise data collected can be directly compared with the AIS data noise mapping.

Other ways of mapping of shipping noise

Towed array of Hydrophones: The use of a moving array - such a line array towed behind a moving AUV - provides distinct advantages for the measurement of the ambient noise field. Using both simulation and experimental data, this iterative noise field measurement technique can provide a continuously updating calculation of the local ambient noise field, including accounting for moving targets.The marriage of AUVs and lightweight towed arrays is a natural progression in the development of littoral autonomous sensing networks for applications such Anti-Submarine Warfare, marine mammals or ambient noise measurements.[23]

Multiple AUV formations: In the future, it may be possible to employ large numbers of autonomous marine vehicles to perform tedious and dangerous tasks, such as ocean survey and minesweeping. Hypothetically, groups of vehicles may leverage their numbers by cooperating. A fundamental form of cooperation is to perform tasks while maintaining a geometric formation. The formation behavior can then enable other cooperative behaviors. In many papers, a leader-follower formation-flying control algorithm is described . This algorithm can be applied to one-, two-, and three dimensional formations, and contains a degree of built-in robustness.[24]

Other AUV Applications

Commercial:The oil and gas industry uses AUVs to make detailed maps of the seafloor before they start building subsea infrastructure; pipelines and sub sea completions can be installed in the most cost effective manner with minimum disruption to the environment. The AUV allows survey companies to conduct precise surveys of areas where traditional bathymetric surveys would be less effective or too costly. Also, post-lay pipe surveys are now possible, which includes pipeline inspection.

Research:Scientists use AUVs to study lakes, the ocean, and the ocean floor. A variety of sensors can be affixed to AUVs to measure the concentration of various elements or compounds, the absorption or reflection of light, and the presence of microscopic life. Examples include conductivity-temperature-depth sensors (CTDs), fluorometers, and pH sensors. Additionally, AUVs can be configured as tow-vehicles to deliver customized sensor packages to specific locations.

Application Specific:An example of an AUV interacting directly with its environment is the Crown-Of-Thorns Starfish Robot (COTSBot) created by the Queensland University of Technology (QUT). The COTSBot finds and eradicates crown-of-thorns starfish (Acanthaster planci), a species that damages the Great Barrier Reef. It uses a neural network to identify the starfish and injects bile salts to kill it.

Hobby: Many roboticists construct AUVs as a hobby. Several competitions exist which allow these homemade AUVs to compete against each other while accomplishing objectives. Some participants in competitions create open-source designs.

Air crash investigations:Autonomous underwater vehicles, for example AUV ABYSS, have been used to find wreckages of missing airplanes, e.g. Air France Flight 447,[13] and the Bluefin-21 AUV was used in the search for Malaysia Airlines Flight 370.

Military applications:
Intelligence, surveillance, and reconnaissance
Mine countermeasures
Anti-submarine warfare
Inspection/identification
Oceanography
Communication/navigation network nodes
Payload delivery
Information operations
Time-critical strikes [25]

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