Research Note

3D Shipping Radiated Noise Mapping

Rijul Dhingra*, Arnab Das, P. Shridhar****

* Birla Institute of Technology and Science, Pilani
** Maritime Research Centre, Pune
** Maritime Research Centre, Pune

1. INTRODUCTION

Pollution in the ocean is not just about the dumping of harmful chemical, physical or biological substances into the sea, but also about the increased ambient noise. Ocean ambient noise results from both natural and anthropogenic (human-induced) acoustic sources, with the latter being closely related to the maritime shipping industry [1]. The behavior of acoustic waves in the Indian littoral waters is a domain that has a potential for extensive studies and mappings. The Tropical Littoral Waters of the Indian Ocean Region (IOR) result in sub-optimal performances in SONARS with up to 70% drop in the performance due to unfavorable medium conditions. [2] The project undertaken is a step forward in the direction to explore and build a better acoustic capacity in the Indian Ocean Region (IOR) required for the enhanced Underwater Domain Awareness (UDA). A 3D sound map is capable of displaying the variation of sound with various depths along with the surface variation of the sound. This mapping and characterization of distant shipping components of ambient noise in shallow water can aid in the sensor deployment for efficient AIS data collection, setting up inland waterways and communication channels. The project uses data from previous physical measurements made to validate the simulations for the specific region. This note presents the work carried out in simulating the AIS data to map the noise levels as a Raised-Relief Map in the Indian littoral waters of the Arabian Sea, IOR.

2. AIS DATA

Automatic Identification System (AIS) is an automatic tracking system that uses transponders on ships and is used by vessel traffic services (VTS). The information provided by the AIS equipment includes Unique Identification, Position, Course and Speed. AIS is intended, primarily, to allow ships to view marine traffic in their area and to be seen by that traffic. [3] AIS data serves the purpose of surveillance in the ocean, keeping a record of all marine traffic in a region. However, AIS data collection is not an error free procedure, with many inadequacies in the form of data lag, data repetition, and the absence of a considerable amount of marine traffic as a result of irregular frameworks and implementations of transponder requirements on marine traffic. Dark ships are also another source of shipping noise in a region which do not get included in the AIS data. However, the AIS data can be treated as a valid source for calculation of noise levels in a region. We must note that that the AIS data does not by itself collect the noise emission values from the ships, but instead contains the parameters required to calculate these noise radiations. Wittekind model is a noise source model which describes ship noise as a combination of three contributions, which arise from low- and high-frequency cavitation and machinery noise. These noise sources are linked to vessel properties, such as displacement, hull shape and machinery specifications. [4] AIS data is used for various applications in today’s age including but not limited to collision avoidance, maritime security, aids to navigation, search and rescue, accident investigation and ocean current estimations. The AIS data has been used to source the parameters required for the calculation of shipping noise required for the course of this study.

3. NOISE MAPPING

A Noise Map is a map of an area which displays the varying noise levels in a region in the form of a color-coded map, also called heatmap. In some cases, the noise levels may also be shown in the form of a contour map, which has the contour lines showing the boundaries between different noise levels in an area. [5] With the rise in marine traffic over the years, the anthropogenic contribution towards noise in the ocean has also increased exponentially. Mapping the ambient noise in the ocean in the form of a noise-heatmap opens the horizon to study spatial variation of sound. The noise maps can also be made using the natural sources of sound, for example snapping-shrimps contribute to the ambient noise in the ocean. A noise map of noise in water can be a source for conducting studies on various domains and is a crucial step in moving towards exapanding the understanding of the Underwater Domain. The measurement of noise levels underwater can be made using a device called Hydrophone. This device needs to be placed at the location of interest and it directionaly detects the sound in the region. However, this is a very tedious process of taking measurements and it is not physically possible for such measurements to be taken for the entire oceans. Instead, simulations that use shipping noise data from AIS or any form of tabulated noise emissions can effectively and accurately measure the total noise at a particular point in the oceans. This study involved simulating primarily use PyRAM model for transmission loss calculations, and Wittekind model for noise emission values using the AIS data for source parameters.

4. 3D MAPPING

A 3D mapping means profiling of objects in three dimensions to map the objects in real-world. While there are several ways for a 3D profiling of an area or object, the method which measures the depth of an object or feature from focus is the most applicable in terms of Underwater Radiated Noise (URN) analysis. One of the best benefits of 3D mapping is that it provides the latest technical methods for visualisation and gathering information. Knowledge visualisation and science mapping become easier when a 3D map is available for the object/area under study. A Z value (other than x and y), gives an enhanced depth when you are collecting data for Geographical Information System (GIS) analysis. [6]
A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map, which enables us to more easily see, analyze, and understand patterns and relationships. [7] The GIS sytem used in the course of this study was QGIS, an open source software mapping software to display the relation between the 3D model and its location. 3D mapping proceeded with the help of Surfer, a contouring and modeling software.

5. UNDERWATER ACOUSTICS

Underwater acoustics is the study of the propagation of sound in water and the interaction of the mechanical waves that constitute sound with the water, its contents and its boundaries. Underwater acoustic propagation depends on many factors. The direction of sound propagation is determined by the sound speed gradients in the water. In temperate waters, SOFAR (sound fixing and ranging) channel, guides propagation of underwater sound for thousands of kilometers without interaction with the sea surface or the seabed. [8] Hence, the variation of noise levels on the water surface and the variation of these levels with depth form a crucial part of underwater acoustics. Such variations have the need to be mapped and studied for a better understanding of the behaviour of sound underwater, especially in the Littoral waters of the Indian Ocean Region (IOR) which serves as an unfavourable zone for most acoustic communication technologies. Certain straightforward beneficiaries of such studies are SONARs, BioAcoustics and Underwater Navigation & Tracking. Underwater Noise is measure through hydrophones which are the underwater equivalent of a microphone which measures the sound in the region by factoring the pressure changes in the surroundings.

6. CHALLENGES AND OPPORTUNITIES

A) Vulnerability of AIS Data:

The original purpose of AIS was to provide for safety, and not for security purposes. The AIS system was not designed to be resistant to hostile interferences. The major causes that can lead to failure of the AIS data collection system can be identified as 1) Incorrect Data Input to AIS unit 2) Disruption to GNSS (GPS) 3) Degradation or Loss of VHF Propagation – with the first two can be brought about by deliberate broadcast of false information. Hence, there must be a scope of including an integrity check during the collection of AIS data. [9]

B) Only Shipping Noise through AIS:

Making a model of variation of Noise levels in the ocean considering the shipping noise as its only source, while has its own applications and reasons, must not be considered as a reference for noise levels in the oceans. The ocean is filled with different kinds of sounds. Underwater sound is generated by a variety of natural sources, such as breaking waves, wind, rain, and marine life. It is also generated by a variety of man-made sources, such as ships and sonars. [10] This background sound in the ocean is called ambient noise. It must be noted that simulations to calculate the noise levels point proceed via using tabulated data, and thereby can be inaccurate to an unacceptable scale of deviations.

C) Resolution of Data & Processing Limitations:

The procedure of collecting and storing of AIS data to be used for simulations requires many sub-steps to calculate the noise levels in a region. From application of Wittekind model to calculation of Transmission Losses followed by logarithmic summation of noise emissions from individual sources result in a very time consuming procedure. These various calculations also require very intensive computations, and cannot be scaled to the level of creating Live 3D maps displayinh the noise variations in an area.

7. FUTURE SCOPES

A) Project Scalability:

The aim of this project was to take a step forward in creation of 3D sound maps and document such a model to facilitate the replication of the model for other regions across the Indian Ocean and the World's Oceans. The supporting deliverables have been documented and stored in the form of a GitHub Repository online [11] to serve this purpose. A direction in making these models more accurate as well as reducing the processing complexities involved can be to reformulate the PyRAM model. The current model calculates the transmission losses at all ranges between the transmitter and the receiver, while the need in our application is only for the TL to be calculated at the end point. Application of AI & ML can be a direction to solve these issues. Another reason to reformulate the PyRAM model is to calibrate it better with the Indian littoral Waters. The PyRAM model was originally created for the European waters, which have favorable conditions for acoustic technologies in comparison to the Indian Ocean Region.

B) Way Ahead:

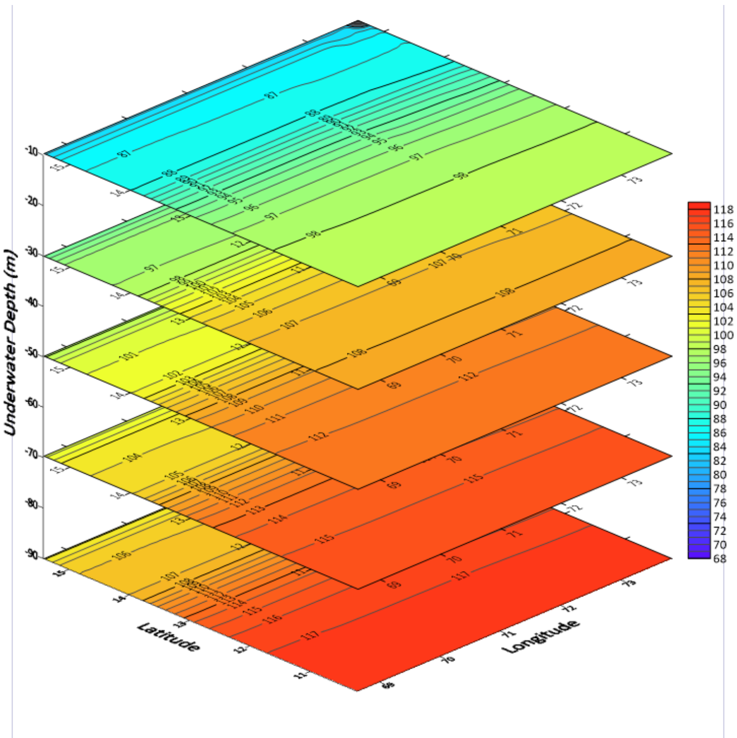
The project, in all its innovation, restricted the study to tabulated noise data from AIS. We must note that the noise in the ocean has many contributing sources apart from ships. These sources can be natural as well as other man-made sources. A way ahead would be to include all anthropogenic noise while creating such maps to actually study the adverse effects of the maritime industry on the marine eco-system. Our growth at all times must be governed by the "sustainability limits." Making a 3D model of Noise variation can also help in Marine Habitat Locations, and or find abnormalities to predict whale/other marine fauna migrations. Acoustic Masking is an increasing concern with the increase in Noise pollution in the Ocean. The study of such maps can help decide Marine Animal Conservation Sites.

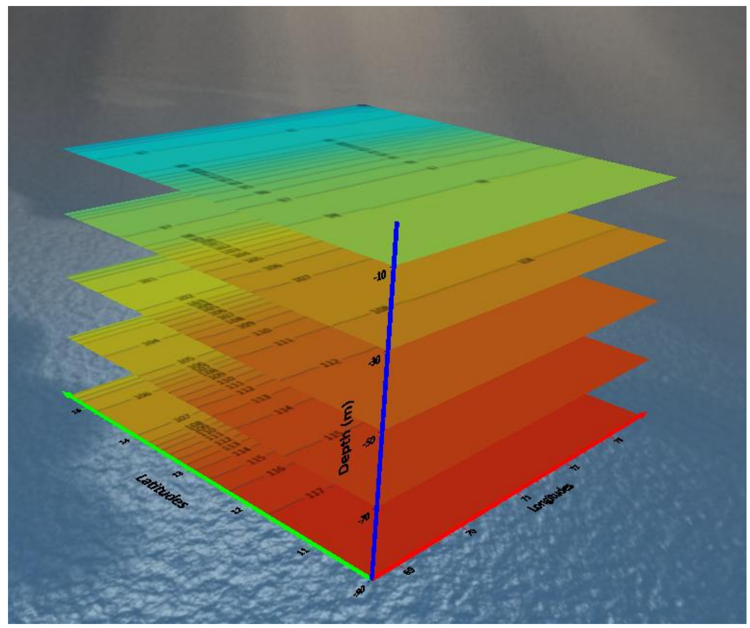
C) Advancing Technologies:

With the daily breakthrough and advancements in technologies, efforts must be made to update the procedure for the development of such a 3D model. These innovations may range from the field of data collection, i.e., finding better implementations of the AIS systems, or the calculation phase as discussed earlier, and even the mapping phase especially with the recent advent in x64 computer architectures along with VR and other Visualisation technologies. During the study to find a suitable software to create a 3D model, I also came across a software called 'Voxler' by Golden Software. [13] Voxler is a 3D data visualization tool that can also be used to create a better 3D model. It wasn't the focus of this project due to time constraints and the high learning curve of the software.

8. RESULTS & CONCLUSIONS

The primary objective of the project was to develop a 3D model which displays the variation of Shipping Noise levels in a region as we move along the surface (Lat-Long) and also factor in the variations observed with depth under the sea level. The model was developed for an area of 90,000 sq. Km in the Arabian Sea region. However, throughout the course of this study, all supporting files that were developed and needed were documented in order to facilitate the replication of such models for other regions as well. We must note that the objective of the project was only to make a 3D model that displays Noise variation and not study, tabulate the varying Noise levels. Such studies are what the model aims to facilitate, to make them easier and more comprehensible. The 3D stack model displaying the Noise variations for the 90,000 sq. Km area in Arabain Sea with depths varying from 10m to 90m under the sea level, along with its 3D visualization:





REFERENCES

[1] Jansson, J. (2012). Liner shipping economics. Springer Science & Business Media.

[2] ORF Online | https://www.orfonline.org/research/underwater-domain-awareness-uda-framework-a-new-perspective-for-the-indian-ocean-region/

[3] https://en.wikipedia.org/wiki/Automatic_identification_system

[4] SSPA | https://www.sspa.se/sites/www.sspa.se/files/field_page_files/2015_sspa_
highlights_61_shipping_and_underwater_radiated_noise.pdf

[5] http://www.noisemap.ltd.uk/home/what%20is%20noise%20mapping.html#:~:text=A%20
Noise%20Map%20is%20a,be%20varying%20all%20the%20time.

[6] GIS | Meeker County, MN - Official Website. https://www.co.meeker.mn.us/539/GIS

[7] GIS Maps - Morganton, North Carolina. https://www.morgantonnc.gov/index.php/government/irms/gis-maps

[8] Underwater acoustics - Wikipedia. https://en.wikipedia.org/wiki/Underwater_acoustics

[9] http://www.iainav.org/News/nws0456-ais-vulnerability.pdf

[10] What are common underwater sounds? – Discovery of Sound in .... https://dosits.org/science/sounds-in-the-sea/what-are-common-underwater-sounds/

[11] https://github.com/FUDA-MRC/3DSoundMapping.git

[12] https://www.goldensoftware.com/products/voxler