Research Note

Acoustic method of dark ship detection in the Indian Ocean Region using low frequency spatio-temporal noise map(Software)

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1. Introduction

A vessel involved in illegal activities within the EEZ of a nation proves to be a grave threat to the national security of the state. Moreover, detecting foreign submersibles is imperative to maritime intelligence. The aforementioned vessels are hard to track as they turn off their AIS transponders so as to avoid detection from authorities.

Ships fitted with AIS shall maintain AIS in operation at all times except where international agreements, rules or standards provide for the protection of navigational information. But more often than not, there occurs a transmission gap in AIS data, which can be momentary or it can last for up to weeks.The AIS can get inactive mainly due to three reasons

1. Due to poor connectivity in regions where there is a lack of satellite coverage or no physical station on nearby coast for receiving the AIS signal.
2. For protection against piracy operations
3. If they are involved in illegal activities such as armed robberies, piracy, terrorism along with human, wildlife, drugs and arms trafficking or if they are involved in trade with sanctioned states.

A ship which has turned off it’s AIS deliberately to avoid detection while being involved in unscrupulous activities of drug and arms smuggling, human and wildlife trafficking or in trade with sanctioned states are referred to as dark ships including foreign submersibles such as submarines.

There have been multiple ventures in the aim to detect these dark ships but none specific to the indian ocean region which has highly fluctuating conditions, or none for detecting submarines or other submersibles.

A software of detecting dark ships in the Indian Ocean region-via identifying discrepancies in the real time noise level obtained from an underwater sensor network and in the spatio-temporal low frequency noise map of the IOR-should be developed along with the classification of those ships.

2. Current state-of-the-art technology developed and the underwater channel

i.There have been some recent developments in using AIS data analysis and satellite imagery to detect dark vessels from various start-ups and government agencies.

a. Synthetic Aperture Radar image analysis

Vessels have high radar reflectivity and appear as bright targets in SAR imagery. The difference in brightness between the vessel and sea surface is distinct in the images captured from the SAR satellite. Machine learning algorithms are used to identify vessels from SAR images and the AIS tracks of the vessel are interpolated or extrapolated to predict the location of individual vessels at the time of SAR acquisition. A finnish company ICEYE is involved in the development of the same. The downside is that it may take several days to access the data and there are fees associated with this data access.

b. AIS Data Analysis

The transmission gaps in the AIS are screened on 3 levels so as to not falsely identify a dark ship. The quality of AIS transmission in the region is checked, post which the duration of time for which the AIS was inactive is noted so as to make sure if a dark trade was feasible in that duration. After this the geographical context is taken into account where the transmission was lost and then the historical sailing activity of the vessel is traced. Windward, an Iraeli company is using this methodology of AIS data analysis. Although it's not possible to detect submersibles via this method.

c. Visible Infrared Imaging Radiometer Suite

Through this method low light imaging data is collected at night (by sensors on a satellite) of heavily lit small fishing boats which are in the trade of IUU fishing. The ability to crossmatch the VIIRS and AIS data opens up the possibility of detecting potentially illegal dark vessels. It fails to detect large cargo vessels and tankers and only works for fishing boats.

d. Radio frequency analysis

A constellation of satellites can independently geolocate a broad range of signals radiated by ships, marine radars, push-to-talk radios, satellite phones and emergency beacons. This broad set of RF signals expands visibility and allows geolocating a dark ship. But it still fails to detect submersibles. HawEye360 is a company using this method but there have been reports of spying and breach of privacy.

e. Passive Oceanic Acoustic Waveguide Remote Sensing

Passive acoustics is the action of listening for sounds, often at specific frequencies or for purposes of specific analyses. Passive acoustic data of ocean ambient noise consists of measurements of sound pressure as a result of the superimposition of sounds generated by several types of events (i.e., rainfall, ship passages, or mammals' vocalizations) to background noise, which is the natural noise in the absence of any sources, whose level is, usually, closely related to the intensity of blowing wind. This method relies on the use of underwater hydrophones as a means to detect all sounds and filter them.

ii. Underwater channel and underwater radiated noise

The marine vessels radiate low-frequency acoustic signals and each vessel based on it’s size and role has a very unique signature. The fluctuations in the tropical littoral waters increase the multipath distortion of signals and hence need to be efficiently tackled if accurate noise signals are to be gathered.

The low absorption rate of water makes sound, especially low frequency sound, travel hundreds of kilometres in the open sea. This is why the low frequency range of URN from a ship travelling a long distance away can still be heard.

A propeller driven ship has multiple noise sources but the propeller is the dominant source generating the highest noise level at frequencies below 200Hz. If cavitation occurs on the blades, the noise level increases further.

3. Challenges

As mentioned above there are many shortcomings and challenges to this process of detecting dark ships effectively

a. Large number of false positives

Switching off AIS for ships is not an infrequent task, a ship at multiple points in its journey can turn off their AIS transponder to either protect themselves from piracy or it may be due to a lack of a strong signal even. This increases the probability of having a large number of false positives which then becomes highly difficult for the state to physically confirm as it is a highly resource intensive task.

b. Signal-to-noise ratio

The poor signal-to-noise ratio in the Indian Ocean Region causes a major deterioration in the transmission of signals from the ships to the hydrophones placed in the ocean. Hence it becomes difficult to plot an accurate noise spectrum of those ships with least signal distortion.

c. Underwater channel

The tropical waters add to surface fluctuations such as temperature and wind, also variations in the site-specific bottom variations increase the multipath distortions which in turn hampers signal transmission.

d. Real time analysis

Since dark ships are a national security concern, it's important to identify these within the shortest amount of time which amplifies the need of a system that can give information in real-time without any delay which is frequent in the images gathered from satellites or in the AIS data accessed. Thus there's also a need for a robust algorithm which can process this real time data as efficiently as possible.

4. Further research scope

There's a visible lack of a method specific to the Indian Ocean Region which can detect surface as well as sub-surface vessels that can work accurately in real time so as to provide actionable information.

a. Acoustic method using low frequency spatio-temporal noise map

An underwater sensor network deployed in a region can provide with the real time noise data which when compared with the spatio-temporal map of the region can be used to generate noise spectrums. Their respective noise spectrums can be plotted by applying the PyRAM and Wittekind models so as to get the data for transmission loss and source level. Comparing the deviations in the spectrums can help in identifying the dark ships in the region around the sensors.

b. Classification of the ships

Machine learning algorithms such as CNN based on auditory-like mechanisms can be used to segregate the identified dark ships into classes of cargo vessels, tankers or submarines.

c. Detecting fishing vessels

Although VIIRS has been implemented in the Indonesian waters to detect the fishing activity in their coastal waters, the method of comparing the noise spectrums can be tested so as to reduce the dependence on satellite imagery.

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