Research Note

Dark Ship Detection And Management System

Siddhesh Dalvi and Dr(Cdr) Arnab Das

A dark ship can be defined as any marine vehicle that cannot be detected by the standard tracking systems used by maritime authorities. These vehicles include all surface and subsurface vessels including but not limited to surface ships, unmanned underwater vehicles, submarines, drones etc.

A common, but potentially unscrupulous practice is for vessel operators to “go dark” to public maritime tracking systems. Some vessel operators may choose to hide from public view for legitimate reasons, which may include hiding from pirates or other navigational security purposes. Though sometimes justified, disabling tracking systems can jeopardize the safety of a vessel and it’s crew, possibly putting them at a higher risk of colliding with another vessel, especially at night. However, this behaviour may indicate that a vessel is intentionally avoiding detection to hide suspicious or illegal activity such as unauthorized fishing activities, terrorism, piracy, hijacking or other illicit operations [1].

Other than disabling the transponders of the tracking systems, certain ships may not be detected due to reliability and manipulation issues. The reports received may be unintentionally incorrect, jammed or deliberately spoofed or tampered with [2]. Any receiver relies on a constant supply of power and internet connection in order to send a consistent stream of transmissions to a centralized server. Much like any computer technology, it can be subject to technical malfunctions. These are especially pertinent in the more remote parts of the world, where internet connections are poor and power outages are more common. Antennas used in the tracking system can also be affected by adverse weather conditions such as lightning strikes. This means that receivers can go offline and subsequently vessels transmissions can be missed. Non-uniqueness of MMSI numbers and signal interference in crowded areas also add to inaccurate data [3].

AIS was developed by the IMO technical committees as a technology to avoid collisions among large vessels at sea that are not within range of shore-based systems [4].

Hence, incorrect AIS data is also harmful for the safety of the ship itself. An effective management system can help to detect such dark ships and prevent the illegal activities that may be intended. Due to the hazards posed by a ship going dark, it is not only necessary to identify such ships but also create an effective real time management system which enables continuous monitoring of a particular area so as to avoid any threatening activities or navigational hazards. It also provides a method for disaster response and management for the respective authorities.

Applications

The issue of a dark ship is quite large and hasn't been tackled yet properly. Such a system will be quite helpful for marine authorities and may have a wide range of applications, to include a few -

Environmental Protection: We can identify vessels engaged in illegal bilge dumping. Oil spill information from satellites matched with the data from this system will provide a mechanism to identify the polluting vessel and provide key evidence for use in investigation and prosecution [5].

Sovereignty Protection: Such a system will allow us to detect naval vessels encroaching on or transiting Exclusive Economic Zones, territorial waters, or controlled areas. Satellite radar detects dark targets which may be indicative of illegal activities or threats. Nations may implement this system for defence purposes so as to monitor enemy ships and submarines crossing international maritime boundaries [6].

Fisheries Protection: This provides a mechanism to track illegal, unreported and unregulated fishing activities in controlled fishing areas [7]. Alerts can be defined to notify users of ships that have crossed into these user defined geo-fenced areas in order to protect national interests and preserve valuable fish stocks. This behavior may indicate that a vessel is intentionally avoiding detection to hide suspicious or illegal fishing activities, such as fishing in protected areas, trans-shipping illegally caught fish, entering a country's waters without authorization or violating other fisheries laws.

Counter Trafficking and Counter Terrorism: It can find and identify suspicious inbound vessels or those transiting territorial waters, for investigation or interdiction. Such a system may provides key information such as altered course, vessel rendezvousing, sudden speed changes, loitering, geo-fence crossing, and spoofing, to allow users to analyze suspicious vessel behaviour. Accurate detection and tracking enables efficient queuing of patrol assets to intercept targets and maximize “eyes on target”, while minimizing resource and fuel usage. [8]

Navigational Aid: Tracking systems such as AIS were mainly incorporated by maritime officers so as to avoid collision of vessels. A management system will help in avoiding navigational hazards as it can prevent the collision of two vessels out of which one cannot be “seen” due to AIS data not being transmitted by it. [9]

Tools for Ship Surveillance and Dark Ship Detection:

Many tools already exist for ship surveillance, most of them belonging to governments and employed for enemy submarine detection. Tracking mechanisms used along with these systems can provide a way to detect and identify dark ships. This section discusses the various tools that can be used.

Automatic Identification System: The Automatic Identification System (AIS) is a tool for identifying and monitoring maritime traffic by sending and receiving vessel information to nearby ships and coastal authorities on two dedicated VHF radio frequencies [10]. AIS provides information such as unique identification, position, course, and speed, which can be displayed on a screen or an Electronic Chart Display and Information System (ECDIS). Primarily AIS was developed as a tool for collision avoidance and was intended to assist a vessel's watch standing officers and maritime authorities to track and monitor vessel movements [11, 12]. AIS was developed in the 1990s by the IMO technical committee as a high intensity, short-range identification and tracking network. After 9/11 incident in United States, vessels were deemed to have important roles in terrorism case so it was crucial to develop a network that would help vessel monitoring [12]. Therefore, in 2002, IMO SOLAS Agreement included a mandate that required vessels over 300GT on international voyages to fit AIS transponder [13].

Measurement of Radiated Shipping Noise Using AIS: The radiated shipping noise generated by a vessel can be measured by it’s AIS data in conjunction with the Donald Ross Model [14]. The model states that propeller cavitation of the ship and impact of bubbles on the cavitation as the dominant source within the ship generating noise at lower frequencies and thus proposed a formula to estimate the shipping radiated noise using Length, Speed and Draught of the ship, which can be obtained from AIS data. [15] We can get an overview of the total radiated shipping noise in a region of the ships with their AIS turned on, which can be mapped.

Measurement of Radiated Shipping Noise without AIS: Radiated shipping noise can be measured without AIS as well and can in fact give a more accurate solution than the

Donald Ross formula. The use of a network of hydrophones in appropriate configurations can give us quantitative information about the radiated vessel noise. A hydrophone is an underwater device that detects, measures and records underwater sounds from all directions [16]. They are a unique type of transducer intended to make non-intrusive, absolute measurements of pressure waves over an extremely wide bandwidth [17]. When submerged in the ocean, a ceramic hydrophone produces small-voltage signals over a wide range of frequencies as it is exposed to underwater sounds emanating from any direction. By amplifying and recording these electrical signals, hydrophones, Measure Ocean sounds with great precision. Using this information, we can create a map of the radiated shipping noise in a particular region. A mismatch in this map and the map created by AIS data can give us understanding of the dark ships present in a region.

Sound Surveillance System: In the mid-1950's, during the Cold War, the US Navy installed an underwater surveillance system to track submarines. The Sound Surveillance System (SOSUS) is a multibillion-dollar network of hydrophone arrays mounted on the seafloor throughout the Atlantic and Pacific oceans. The SOSUS system takes advantage of the sound channel that exists in the ocean, which allows low-frequency sound to travel great distances. This channel is called the SOund Fixing And Ranging, or SOFAR, channel. Low-frequency sound generated by submarines can be detected at long ranges by hydrophone arrays located on continental slopes and seamounts, and connected by undersea cables to onshore facilities. These hydrophone arrays listen to the ocean, record sounds, and transmit the data back to shore stations for analysis [18].

Fish-Hook System: The Japanese Maritime Self-Defense Force (JMSDF) has a comprehensive architecture of ocean surveillance systems for monitoring the disparate challenges it faces in supporting its defensive activities, including SOSUS (sound surveillance system)-type submarine detection and tracking systems, high frequency direction finding (HFDF) facilities, ocean surveillance ships, and maritime surveillance aircraft. Information from all of these systems is integrated into the JMSDF's Ocean Surveillance Information System (JOSIS), the current version of which is officially called the JMSDF OSIS Evolutionary Development (JOED) system, at the JMSDF's Fleet HQ at Yokosuka, in Kanagawa Prefecture, on the western side of Tokyo Bay [19].

National Command Control and Communications Intelligence Network: India is involved in the construction of an undersea network of seabed-based surveillance sensors stretching from the tip of Sumatra right up to Indira Point. Once completed, this network will be an integral part of the existing US-Japan 'Fish Hook' sound surveillance network that will play a pivotal role in constantly monitoring all submarine patrols mounted by China's PLA Navy (PLAN) in both the South China Sea and the IOR. This network will in turn be networked with the Indian Navy's (IN) high-bandwidth National Command Control and Communications Intelligence network (NC3I), which has been set up under the IN's National Maritime Domain Awareness (NMDA) project. At the heart of the NC3I is the Gurgaon-based Information Management and Analysis Centre (IMAC), whose systems integration software packages were supplied by Raytheon and CISCO [20].

Satellite Detection: Certain commercial technologies use multiple satellites and sensors efficiently to collect data for the purposes of detection of vessels that aren't broadcasting AIS information. This is done by using radar satellites to do broad area imaging to get general patterns of marine traffic. Optical imagery satellites would provide coverage for a smaller and more specific area, known as choke points [21, 22].

Future Scope

The field of dark ship detection and ship surveillance is a relatively unexplored one. Most of the systems already in place are defence-based systems employed by nation-states. Research on application specific systems to target smaller areas has not been done substantially. Given below are some of the areas on which research can be done.

Use of Artificial Intelligence and Machine Learning in Ship Detection and Identification: Artificial intelligence and machine learning can be used to detect anomalies in AIS data by exploiting radar data [23]. These solutions are based on generating normality models from data gathered on vessel movement, mostly from AIS [24]. While lots of work has been done in vessel identification and classification, work still needs to be done in estimating shipping noise using ML, based on sensor or AIS data.

Selection of Hardware and for a Shipping Radiated Noise Solution: Most existing solutions to maritime surveillance involve the use of radar and satellite detection. Not a lot of work has been done in identification of ships using radiated shipping noise for security purposes rather than defence purposes. Research has to be done on the sensors to be used for a particular region in which such a system needs to be set up according to the geographical and environmental conditions prevailing in that area and also when and how measurements will take place needs to be decided. Other than just using hydrophones, a detection system can work in conjunction with other methods of surveillance and give a combined, more accurate description of the vessel traffic in the region.

Establishment of Command Centers: There needs to be a command center which collects, stores and analyzes the data incoming from the system. This includes software for data processing and a data acquisition unit. The necessary communication frameworks and response system need to be made. Such command centers exist with nation-state surveillance systems such as NC3I, but work has to been done on how to execute this for a specialized area for security reasons.

Robust Regulatory Framework: "Dark ship" is a relatively unused term and there are not much references to it in common literature. The international regulatory framework on how to handle dark-ships is quite weak, with most focus on the sharing and protection of data provided by tracking systems. There are no strong set of rules available. Dark ship may be a security as well as defence problem so it is necessary to set up a robust framework as to tackle the issue of dark ship and avoid international maritime discrepancies.

Creation of a Real Time System: In order to create an effective management system, the dark ship management system needs to send data in real time. The frequency in which AIS data is sent from the transponder and that of this management system need to be in correspondence so as to get meaningful data. Ships send AIS data at certain intervals depending on their speed and transponder class. The detection system should be able to process and update the data at a speed quicker than that of the AIS update frequency. If this is not achieved, old AIS data will be used for comparison and thus the system will be faulty. For this purpose, the system needs to be optimized appropriately, so that it can work in real time.[25]

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