

**Name:** Rouben Azad

**Rank and service or organization:** LT Navy

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**Advisor:** Dr. John V. Monaco

**Co-advisor:** Dr. Geoffrey Xie

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LIST OF ACRONYMS AND ABBREVIATIONS

AIS Automatic Identification System

SOG Speed Over Ground

COG Course Over Ground

ML Machine Learning

NPS Naval Post Graduate School

MMSI Maritime Mobile Service Identity

DIM Dimension

ROT Rate of Turn

PIM Position of Intended Movement

CPA Closest Point of Approach

GPS Global Positioning System

NOAA National Oceanic and Atmospheric Administration

[list of classifier acronyms to follow]

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I would like to thank my future wife, advisors and cohort for their support in this new field I’ve experienced in my educational years at NPS. To further strengthen my and motivate me in this process, thank you. (more to add)

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# INTRODUCTION

An Automated Identification System (AIS) [2] is the primary source of identification for surface vessels on the high seas. Almost all ships are equipped with them, and they are used frequently by other vessels to aid in collision avoidance. The information that AIS provides, such as, unique identification, course, position, speed, tonnage, and ship dimensions, is especially useful in and around ports. Port controls use this data to direct traffic and maintain channel control. Maritime authorize and asses this data, and physically verify the vessels for security, or otherwise.

Although this data is relied on heavily by all factors listed above, and more, it is easily “spoofed” -- meaning, it can be altered before transmission. Some vessels use spoofing to hide their identity or ship loadout. Security risks are on the rise due to frequent use of spoofing data from sea-going vessels, especially in this technological age where data altering is common. [1]

Artificial intelligence (AI) and machine learning have been a new facet of discussion. This fairly new technique can have a powerful impact on information sharing across vessels because it has the ability to predict and prevent security risks at sea.

Our main steps in building a machine learning algorithm are; preparing the data, choosing our model, training, evaluating, tuning and prediction. This will be discussed further in the methodology section. [6]

AIS data will be used to train a model to make predictions and decisions without explicit programming. The goal is to find outliers in this data by the machine’s use of pattern recognition, classification, and regression algorithms, which will point us to our anomalies.

This machine learning algorithm will parse the AIS data to detect and categorize anomalies which will help maritime authorities gain deeper knowledge on risky vessels.

Most vessels out at sea don’t have fraud detection that can prevent against spoofing. Automated anomaly detection could potentially aid in collision avoidance. By gathering information on high-risk vessels, it also enables watch standers to make better decisions at sea.

## Thesis Objective

This research will demonstrate how a machine learning algorithm can effectively identify a wide variety of anomalies in vessel dimensions, identification, ship to ship networking, and movement behaviors in an Automated Identification System (AIS) database. By analyzing this data through machine learning, we can show a whole new field of possibility for maritime security by supplying them with additional tools to enable better security procedures out at sea and ports. Machine learning is now being used across all fields of technology and the United States Department of Defense can benefit greatly by this implementation. Sea-going vessels are notorious for using spoofing technologies to alter AIS data. This thesis will involve development of an algorithm that can spot these anomalies and categorize vessels as seen fit.

This thesis will show how a machine learning algorithm can be used to detect abnormal activities extracted from this AIS data. This algorithm will be able to categorize vessels by their maneuvers, behaviors, and network connections by using pattern recognition, observing anomalies, and finding outliers.

## Benefits of this study

If our hypothesis is correct, this work will help maritime authorities gain deeper knowledge on high-risk vessels and help eliminate misinformation and illegal activities at sea. This will also equip watch standers with an improved situational awareness aided by the use of this algorithm, which will enhance the information received by AIS for better decision making and judgment control.

## Methodology

This thesis will involve working with programming languages such as python, with additional modeling interfaces for analyzing and assessing data. The tools that will be utilized for this work are IPython for its interactive shell commands that support data visualities and graphical user interface (GUI) toolkit; and Python’s Pandas and Matplotlib, which are both great tools for data analysis and modeling. Matplotlib will be primarily used for plotting libraries in its 2D plotting interface.

The first step in the process is data preparation, by loading our data into a suitable place. Then begin parsing the data using an established algorithm with a few modifications to support the changing data structures. After completion of the parsing and organization, a model will be constructed that suits the data. Afterword’s we will train our model with the given data, and incrementally improve its ability to make better predictions. Once the training is complete evaluation beings to test the model’s accuracy. From the evaluations we can decide to further improve our training by tuning our parameters. And lastly the prediction step, we use our model to predict the correct answers. [6]

This machine-learning algorithm will be constructed using the previously stated methods. There will be multiple levels of AI to be established in this structure, beginning with data analyzation using 2D models with Matplotlib; machine-learning acquisition and testing; data categorization; and ultimately, anomaly detection of real-world historic AIS data.

The second step will be analyzing large amounts of data over a long period of time using the first step. Afterwards, the algorithm will be put through validation to narrow down errors and complete the program.

Finally, a result of the stress tests will be documented and improved upon. In turn, this program will be used to analyze data in real time to provide a quick response to maritime security.

## Thesis Structure

In the follow-on chapters we will cover Literature Review in Chapter II, Data Management in Chapter III, Modeling and Analysis in Chapter IV and Summary and Future Work in Chapter V. In Chapter II we will cover, all related fields of research that have been done at NPS regarding AIS, anomaly detection and vessel network distribution. The focus on these topics are particularly helpful in our research and could help improve and further the study in this subject. In Chapter II we will concentrate on data management and manipulation to extract the desired information necessary to expand our hypothesis. This will be done through various methods that involves transformation and matrix building to allow for data arrangement. We will also define different tools and techniques used to model our data and portray vessel interaction, trajectories and ship networking. In Chapter IV we showcase the different methods applied and their findings via graphical and analytical methods to further enhance the usage of the machine learning algorithm. In Chapter V we conclude our finding and elaborate on the successes and failures of our modeling techniques. We further pose more solutions that could be established to advance our objective through additional research.

# Literature review

Recent events in naval history suggest the use of AIS data to be more meaningful. In [date] [ship] collided with [ship] due to error on behave both vessels and watch standers. There is other shipping related collision that occur on occasion. AIS data and machine learning tools could be used to limit these collisions by understanding networking behaviors of vessels and their trajectories. Various research has been done on this topic; vessel trajectory prediction, anomaly detection,

# Data management

In collaborating with the coast guard, we’ve accumulated AIS data for 3 different ports in the United Sates: San Diego, San Francisco and Norfolk Virginia to start our initial testing and analysis. The data is comprised of 21 columns that defines each vessel with various details such as latitude and longitude, speed, heading etc., we will further elaborate on these in future sections. All 3 data sets are historic, and they rang in a year period from January 2018 through Jan 2019. The AIS data shows all vessels that transited the area with the given Latitude/Longitude roughly covering the size of the harbor.

Each dataset is broken up by moths totaling 12 sheets. Initially python is used to concatenate the data into a data frame for further analysis and feature selection. A graphics tool is used to plot the data without any manipulation to observe the normal state. Furthermore, other various plots are displayed to show the effects of the feature selection.

# appendix. Optional

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Hawks, Mathew A. “Graph-Theoretic Statistical Methods for Detecting and Localizing Distributional Change in Multivariate Data,” Ph.D. diss., Naval Postgraduate School, Monterey, CA, 2015. (**Chicago N-B style**)

Naval Postgraduate School. (2017). Thesis\_template\_times [Word template]. Monterey, CA: Naval Postgraduate School. Retrieved from https://my.nps.edu  
/documents/105790666/106471216/Thesis\_Template\_Times.docx (**APA style**)

[1] B. Orend, *Morality of War*, 2nd ed. Tonawanda, NY: Broadview Press, 2013. (**IEEE style**)

Kyle Wilhoit and Marco Balduzzi, “Vulnerabilities Discovered in Global Vessel Tracking Systems.” TrendLabs Security Intelligence Blog, 8 Aug. 2014, blog.trendmicro.com/trendlabs-security-intelligence/vulnerabilities-discovered-in-global-vessel-tracking-systems/.

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