UVA DATA SCIENCE

Detecting Illegal Fishing with Automatic Identification Systems and Machine Learning

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1 May 2024

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Stakeholders

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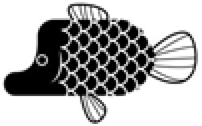
Introduction 

Illegal, Unreported, and Unregulated (IUU) Fishing

- Widely defined – fishing outside of local or international regulations
- Critical issue impacting health of marine ecosystem and global security
- Estimated to cost $10-23 billion annually

Automatic Identification Systems (AIS)

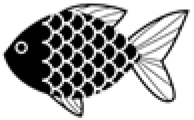
- Standardized tracking systems outfitted on all vessels
- Continuously transmits user data
- Utilized for maritime monitoring and collision avoidance
- Very available and easy to obtain

Motivation

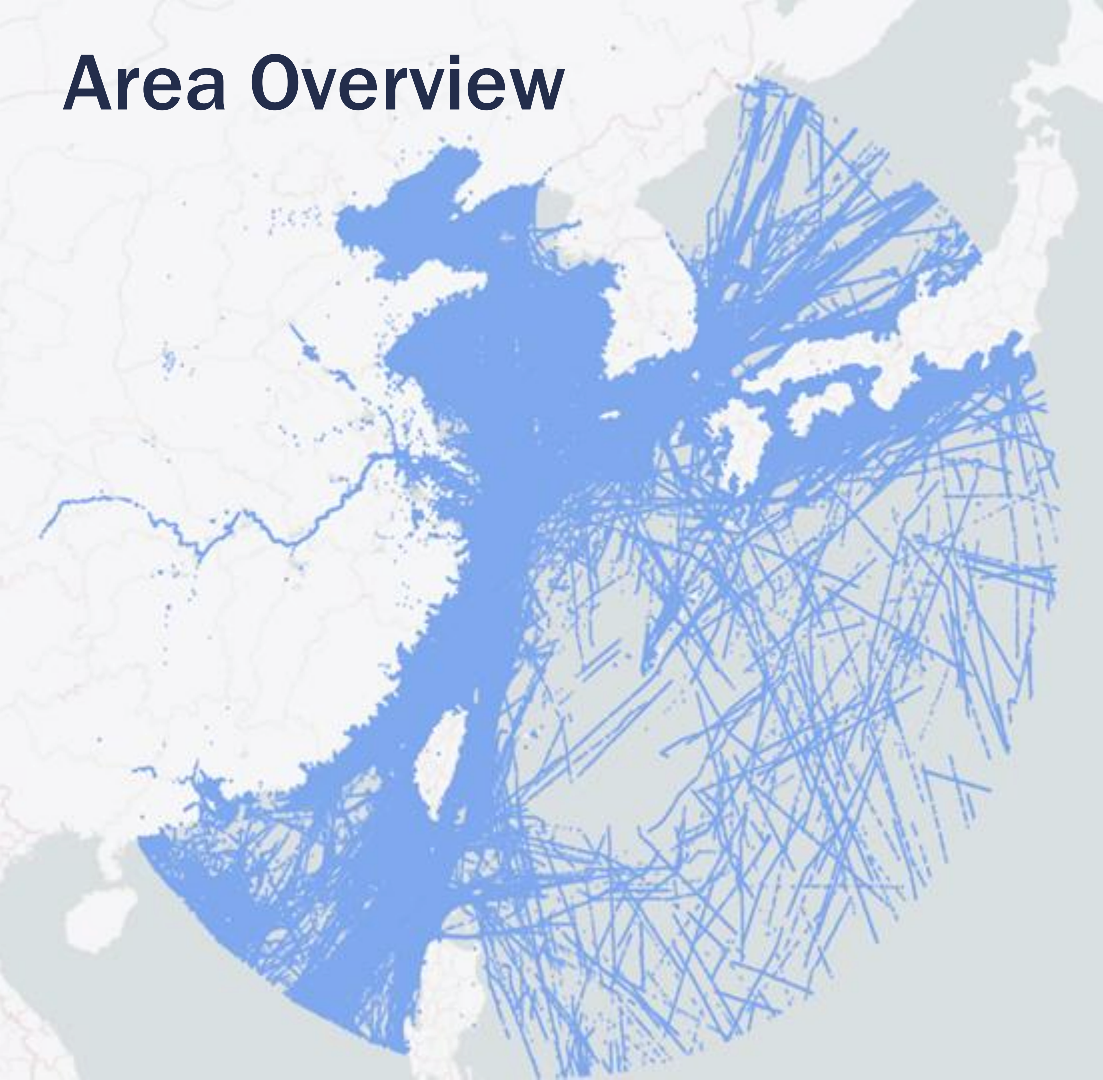
- AIS devices are commonly illegally exploited on fishing nets and buoys to protect large hauls
- Increased need to reform AIS regulations

Goal:

Explore how AIS data can be used to aid in IUU fishing net detection

Data 

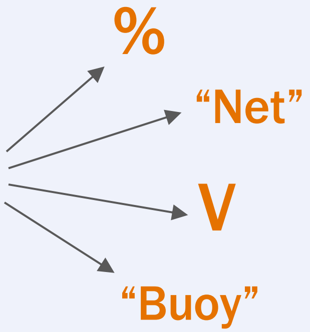
Area Overview



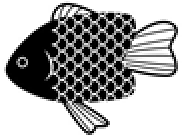
- Region of interest:
  - Southeast Asia
- Spatial, temporal, and user inputted data
- Training set
  - Around 4 days
  - September 1→5 2023
- Test set
  - Around 4 days
  - October 12→16 2023

Assumptions and Limitations

- Certain naming or positional conventions are suggestive of fishing nets



- Computational limitations led to restricted region of interest and timeframe

Methodology 

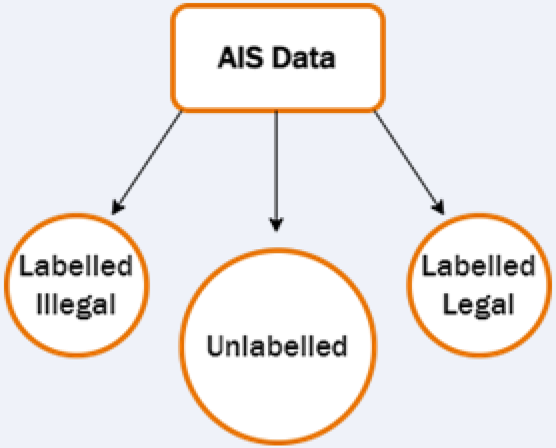
Pre-Processing

- Aggregate data by distinct device ‘trips’
  - Unbroken period of AIS transmission
  - Included scaled parameters for speed, heading, and positioning
- ***Red flag***: Indicators of non-standard naming conventions and movement
  - Score from 0→4
  - Used for modelling analysis

net_name	Names including a ‘V’, ‘%’, ’buoy’, or ’net’
mmsi_length	MMSI values not equal to 9 digits
spawn_offshore	Vessels whose first transmission is offshore (1 nautical mile off coastline)
spoof	Devices with unreasonably high calculated speeds (≥ 150 knots)

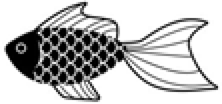
Pseudo-Labelling

- AIS dataset is unlabelled
  - Select models utilized pseudo-labels for training
- Pseudo-labelled confident points based on ‘red flag’ conditions
  - Illegal: Bad *net_name* and ≥ 3 total red flags
  - Legal: No red flags



Approaches

1. Unsupervised clustering
   - Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN)
2. Semi-supervised classification
   - eXtreme Gradient Boosted trees (XGBoost) and Artificial Neural Network (ANN)
3. Supervised classification
   - ANN

Models 

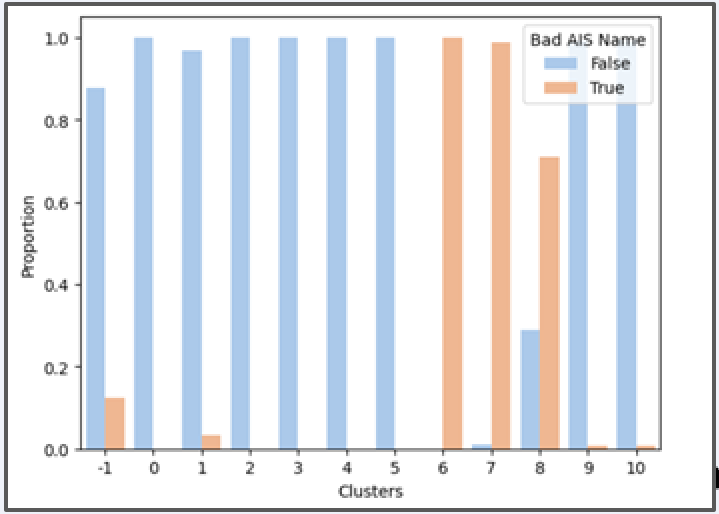
Unsupervised Clustering

- Treats dataset as truly unlabelled
- Clustering with HDBSCAN
  - 2 clustering iterations
- After first round new score is built:
  - Aggregates mean red flag score of each cluster onto respective observations

Unsupervised Clustering Results

- 3 primary clusters identified
  - Reflect 36.2% of total trips in dataset
  - Includes 1% of observations with valid *net_name*
- The developed features may be valid indicators of IUU activity that cannot be detected with naming conventions alone

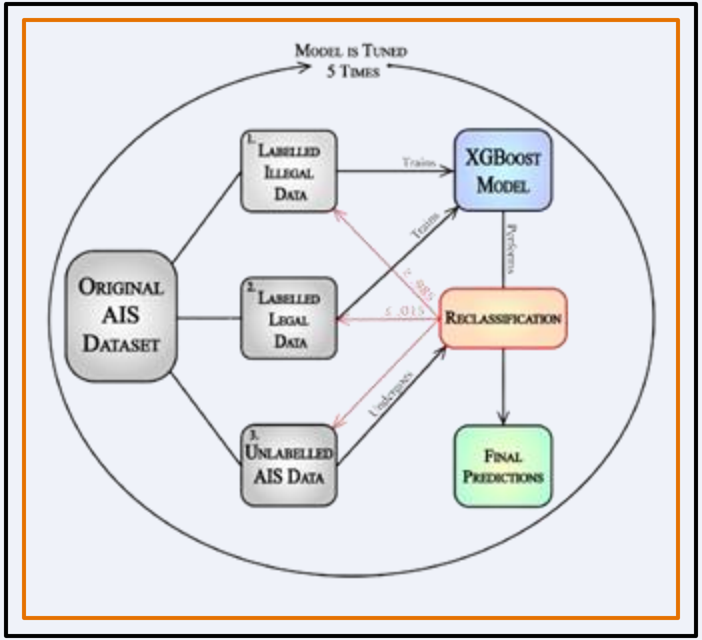
Cluster Results Analyzed by net_name



Semi-Supervised Classification

- Small set of confident pseudo-labelled points, other points are left unlabelled
- Model trained on sample of labelled AIS data
- Iteratively classifies unlabelled dataset if confident and retrains on updated labelled dataset

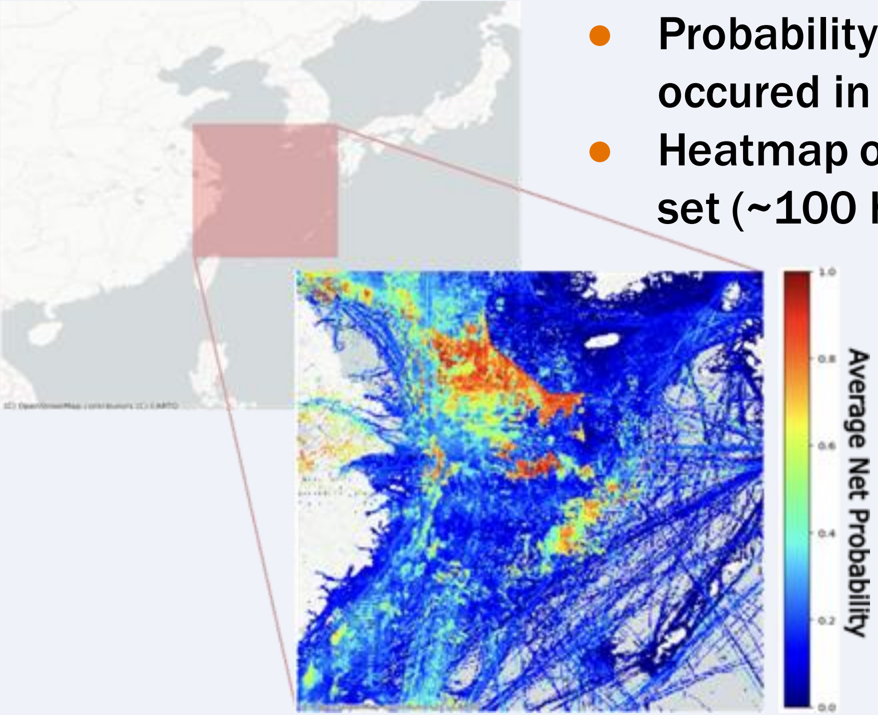
Workflow for XGBoost & ANN



Supervised Classification with ANN

- Uses pseudo-labelled training data once to build model
- Simple ANN predicts binary classification for each AIS trip
    - Same 4-layer ANN framework used for both semi and fully supervised models

Semi-Supervised and Supervised Classification Results



- Probability of 1 indicates illegal likely to have occured in region
- Heatmap of XGBoost prediction results on test set (~100 hours)

Model	Test Accuracy	TPR	TNR
**Semi-supervised XGBoost	0.891	0.915	0.848
Semi-supervised ANN	0.879	0.900	0.842
Supervised ANN	0.867	0.907	0.801

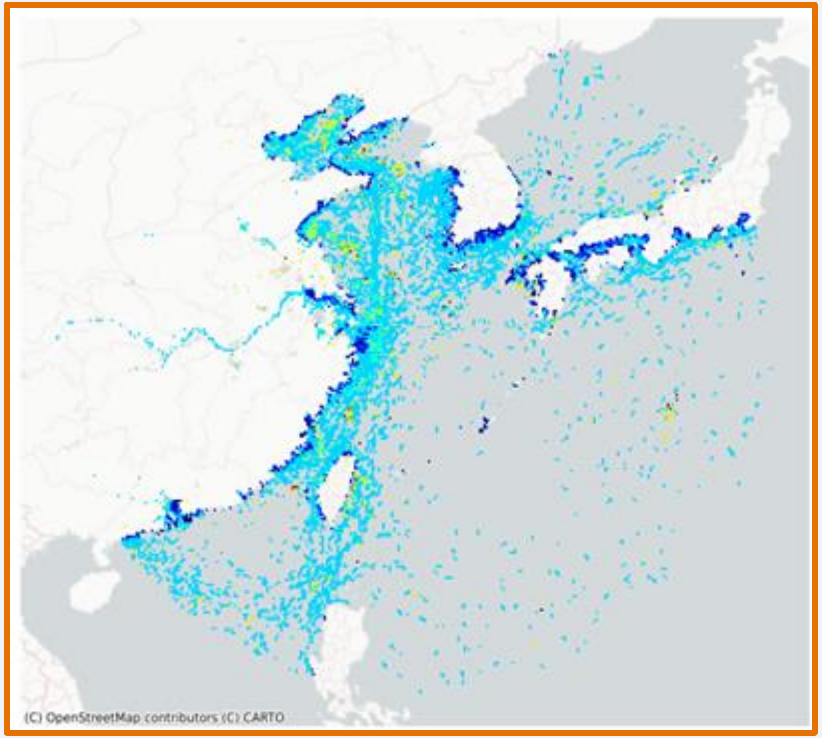
**XGBoost model was the top performer with test set

Regional Analysis

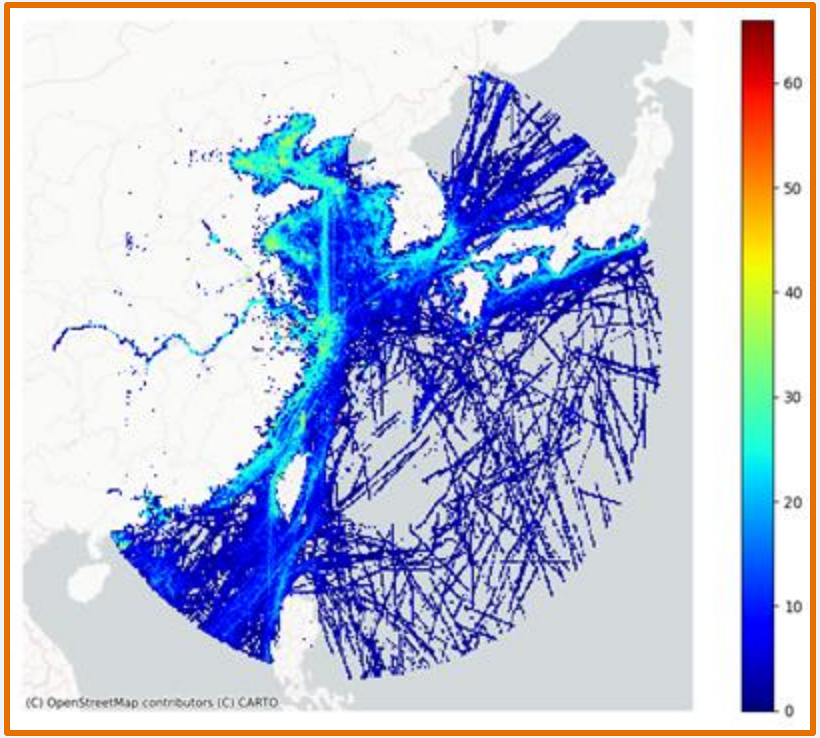
- Divided region into .1°x.1° cells
  - 36 mi^2
- ***hot_score:*** number of unique red flags divided by count of unique vessels
- Position each AIS signal within its corresponding grid cell
- Calculate total number of ‘red flags’ per unique vessel for each cell
  - Aggregate each hours’ score per cell to see which areas showed most signs of illegal activity per day

Regional Analysis Visual Results

September 1st, 1 hour



September 1st, 24 hours



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Acknowledgements

Special thanks to Tara Vallardes, Rebecca DeSipio, and Heman Shakeri for their expertise throughout! We could not have accomplished this without their help. ❤

Capstone Team

- Samuel Brown
- Danielle Katz
- Dana Korotovskikh
- Stephen Kullman