YOLO algorithm for shipping waste discharges detection at Swedish waters based on fused satellite images with ship AIS data

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Problem and Purpose

The tank cleaning operations may pose a threat to the marine environment. Reports from the Swedish national audit office indicate that ships planning to clean sometimes deviate from routine routes, which suggests a role for analytics based on their navigation data e.g., AIS data and remote sensing data. By examining trajectories and their spatial and temporal attributes, it is possible to identify unusual movement patterns and flag potential non-compliant operations.

- Develop a feature engineered ML framework for anomaly detection
- Leverage image-processing algorithms on satellite images to cross-check detected anomalies

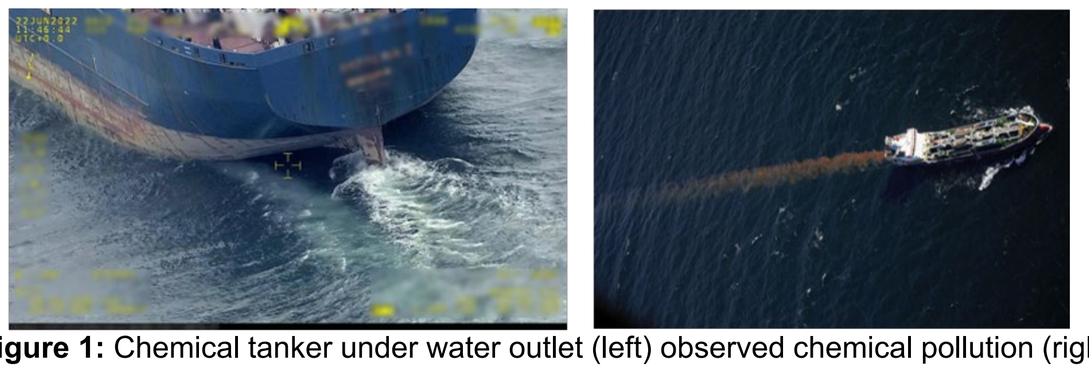

Figure 1: Chemical tanker under water outlet (left) observed chemical pollution (right)

Realization

Convert AIS trajectories into images and apply self-learning method them. For each unlabeled image, two augmented views are fed into an online and a target CNN to produce latent embeddings. The online network is trained to match the target embedding across views, thus learning without labels.

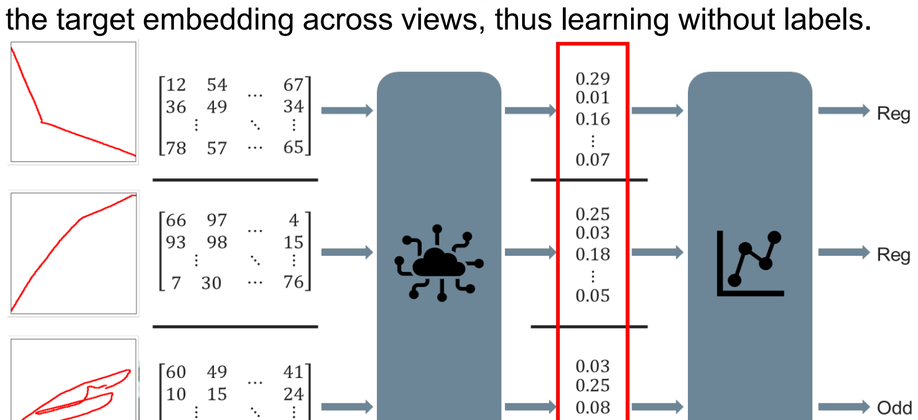

Figure 2: Classify trajectory images with a neural network

Use an active learning scheme to keep expert's knowledge in the loop. The model first predicts on all trajectories and then selects the samples it is least certain about; an expert labels them as regular or abnormal. The model is retrained on new samples.

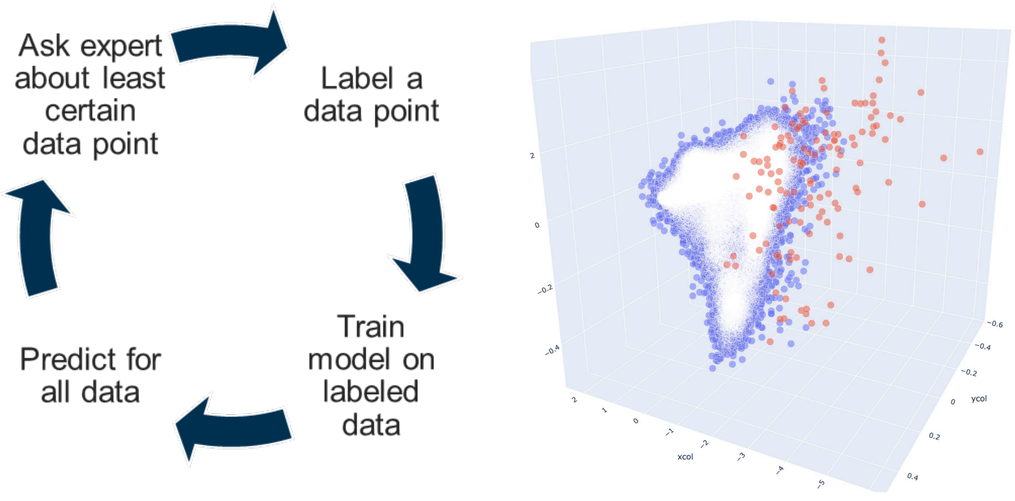

Figure 3: Active learning framework (left) interactive visualization for expert labels (right)

Use data augmentation techniques such as image rotation, cropping and scaling, to enrich the satellite image dataset. The YOLOv11 is used to detect suspected illegal discharges and cross-check them against the identified anomalies.

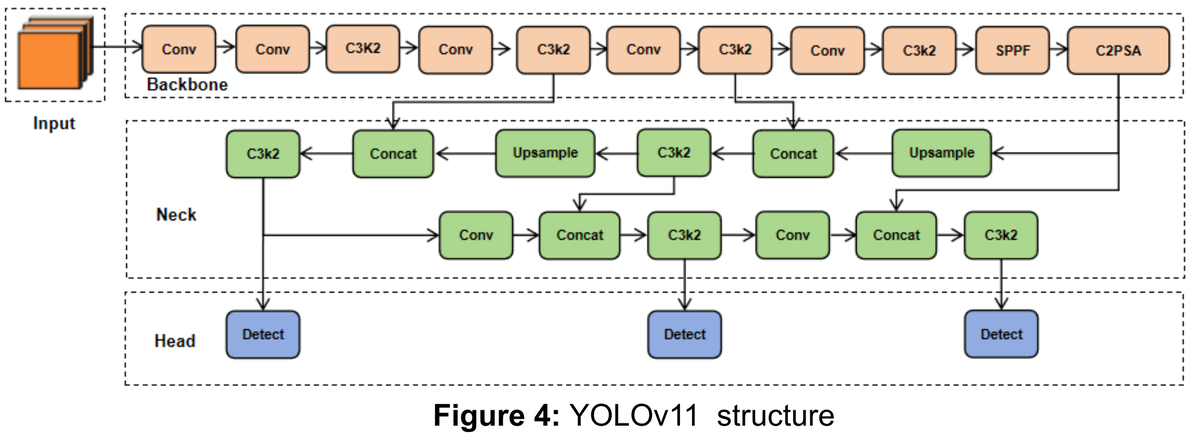

Figure 4: YOLOv11 structure

Results

After vectorizing the trajectory images, Similar images have similar embedding vectors. Then, cluster these trajectory vectors. Some anomalous trajectories can be identified.

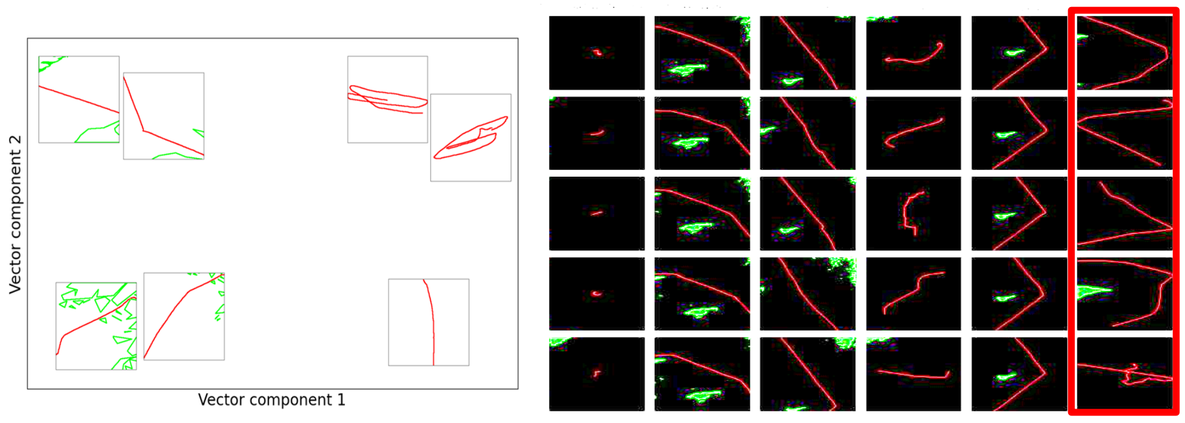

Figure 5: Kmeans cluster for trajectory images

By incorporating expert knowledge through an active learning framework, the performance of classification can be further improved.

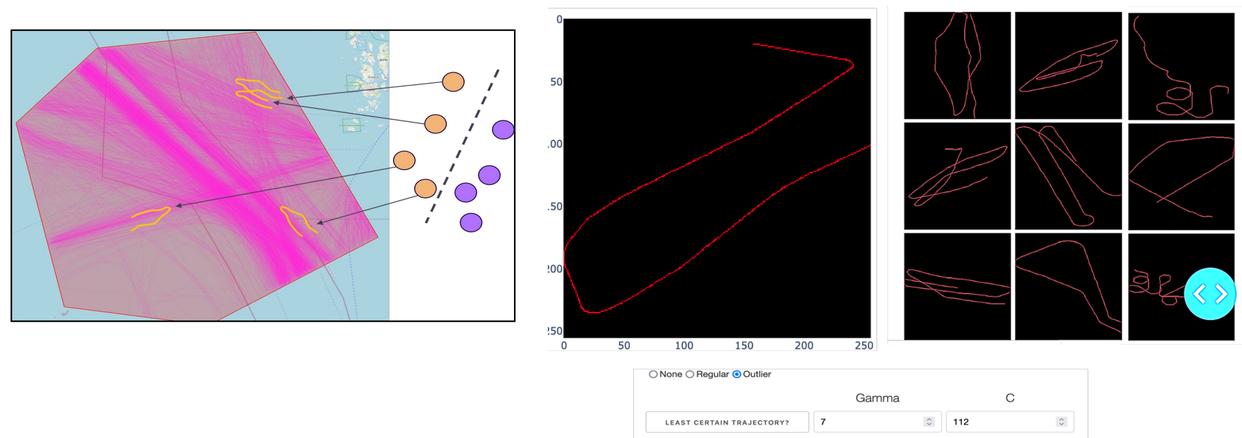

Figure 6: Get adequate predictions with < 100 labels

Suspected illegal can be detected by augmented YOLOv11.

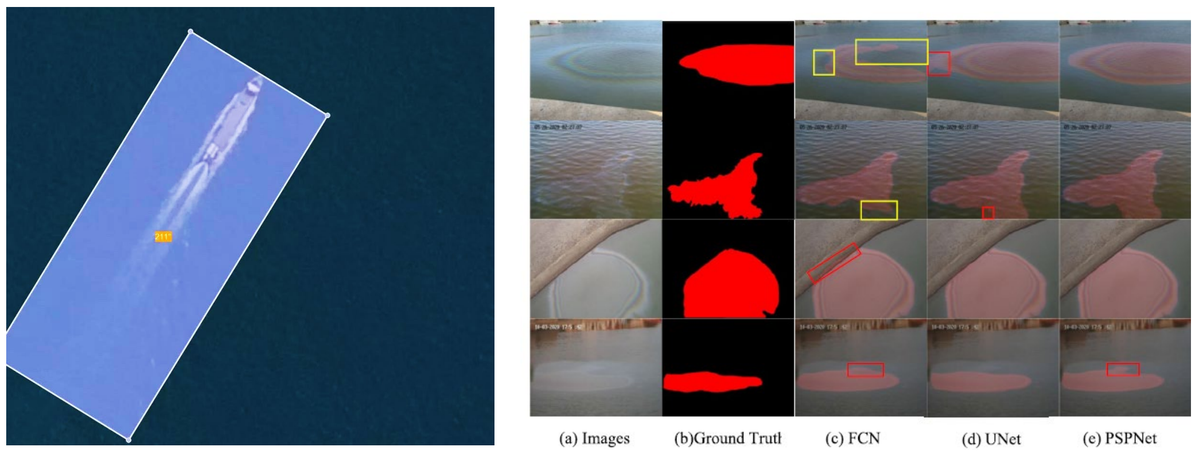

Figure 7: Characters of suspected illegal discharges from images

Outlook and future research:

1. Add external data in extra image layers to improve model
2. Involve Transformer-based trajectory prediction in the model
3. Using satellite images to label illegal discharges

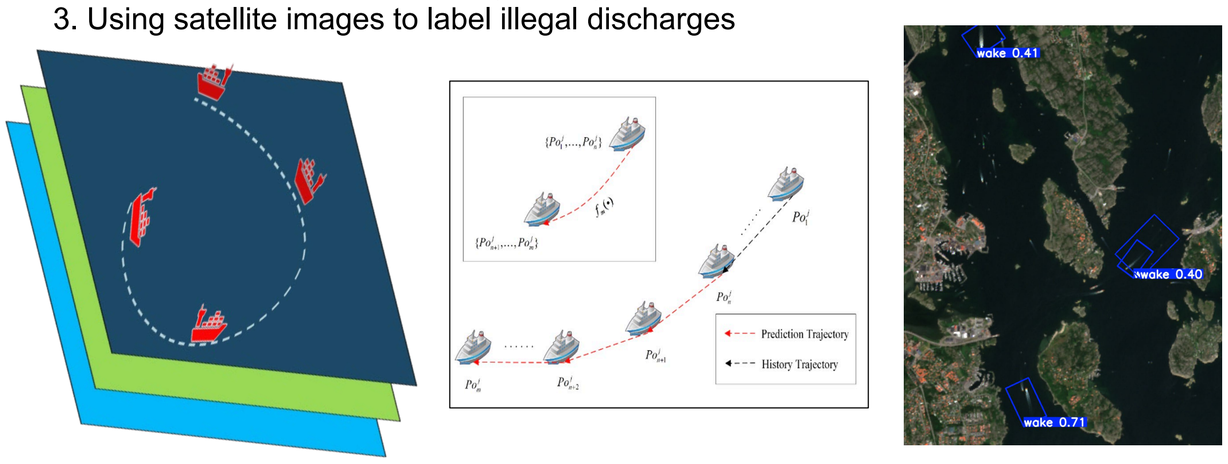

Figure 6: Add extra layers in images (left) trajectory prediction (middle) satellite images for detected points (right)

References

Mao W., Wang S., and Hassellöv I-M. (2023). Pre-study on AIS 'big data' analyses for identification of tank cleaning operations at sea. Technical report to Havs- och Vattenmyndigheten.

Hermansson A. L., Hassellöv I-M. (2020). Tank cleaning and its impact on the marine environment. The Marine Environment Institute's report series: 2020:6.