VAST 2024-MC2 Challenge

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Abstract

This paper presents the comprehensive analysis and visualizations developed by the FES-MC2-1 team for the VAST Challenge 2024, Mini-Challenge 2. The challenge required us to analyze port exit records, transponder ping data, and cargo delivery reports to associate vessels with their probable cargos, identify seasonal trends and anomalies, and detect illegal fishing activities by SouthSeafood Express Corp vessels. Utilizing a combination of advanced visual analytics tools—including Tableau, Python, React, Docker, Postgresql, Nginx and custom-developed solutions from the University of Konstanz—our team uncovered patterns in the data that reveal suspicious activities and significant shifts in fishing behavior following the crackdown on illegal operations.

Index Terms: Applied Visual Analytics [Vast Challenge 2024]: Mini-Challenge 2—Illegal Fishing;

1 Introduction

The VAST Challenge 2024 tasked participants with addressing a scenario set in the island nation of Oceanus, where commercial fishing is a crucial industry but also a source of significant ethical concerns due to illegal practices (fishing in geological preserves, non-seasonal fishing, overfishing). In this challenge, FishEye International, a non-profit organization dedicated to combating illegal fishing, provided a synthesized dataset for analysis, known as the CatchNet Knowledge Graph. This dataset included port exit records, vessel tracking data, and shipping records, which were often incomplete or misaligned. The challenge was to develop a visualization application that could link vessels to their probable cargos despite these limitations, identify seasonal trends and anomalies, and expose illegal fishing activities conducted by SouthSeafood Express Corp vessels and other vessels that performed similar activities.

Our approach to the challenge was methodical and rooted in the principles of visual analytics. We employed a range of tools, such as Tableau and Python for data processing and detecting data anomalies, React and d3.js for developing visualizations, and Chakra UI for creating the frontend. Docker and PostgreSQL were used to create a backend for providing data to our graphs. The methodology involved several key steps:

1. **Data Preprocessing:** We began by cleaning and organizing the datasets to ensure consistency and reliability. This step was crucial, given that the records were incomplete and often required significant manipulation to make them usable.

2. **Visual Analytics Development:** Our primary task was to create visualizations that could uncover hidden patterns within the data, focusing on heatmaps, network graphs, pixel graphs, and temporal analysis tools to link vessels with specific cargos and identify anomalies in shipping patterns. Heatmaps, which represent data intensity using color, were used to highlight areas with high concentrations of activity, such as frequent visits to specific locations that could indicate illegal activities. Network graphs visualize relationships between entities, where nodes represent entities (such as vessels or cities), and edges represent the connections or interactions between them. In the first network graph, it is utilized to find out which vessels delivered the cargos when by comparing the date of the transaction and delivery reports. In the second graph, the cargos which contained the illegal fishes and the cities that they are delivered to are shown. Pixel graphs, which represent data compactly as individual pixels, were used to track the movement of vessels over time across locations. Temporal analysis tools, focusing on the timing and sequencing of events, enabled us to see the overall trend.

3. **Behavioral Analysis:** We analyzed the movement patterns of SouthSeafood Express Corp vessels, comparing them with others to identify suspicious behaviors, such as unusual dwell times and location frequencies, which helped us pinpoint illegal fishing activities. Following enforcement, we monitored how the broader fishing community in Oceanus adapted, observing shifts in fishing routes, changes in vessel behavior, and new suspicious activities.

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2 Related Work

In the field of maritime surveillance and illegal fishing detection, significant research has been conducted to develop and refine visual analytics techniques. One notable approach is outlined by Healy and Reardon [1], where the authors discuss the application of visual analytics to identify and mitigate risk in complex data environments, which has parallels to our own work on detecting anomalies in fishing vessel behavior.

Another relevant study by Zissis et al. [2] presents a graphical representation of fishing vessels, where state nodes and transition arcs are used to model vessel behavior. This visualization technique provided inspiration for our network graphs that map the relationships between vessels and their suspected cargos.

3 Behaviors of Vessels

During our research, we observed all types of vessel (Fishing, Ferry Passenger, Cargo, Research, Tour, Ferry, Cargo, and Other) behaviors in the relevant areas (City, Buoy, Ecological Preserve, and Fishing Ground) by using our visualization tools. As a result of this, we detected some abnormal activities of SouthSeafood Express Corp and some other vessels, and then we matched these activities with some inappropriate fishing.

3.1 Inappropriate Behavior of SouthSeafood Express Corp Vessels

From the beginning of the research, we know that two vessels belonging to SouthSeafood Express Corp. were engaged in illegal fishing activities and were later caught. It can be easily seen in Figure 3 that these vessels (Roach Robber and Snapper Snatcher) were caught after the 20th week. When the number and duration of these two vessels are examined during this period, it is seen that they are more active in city areas. Let's look at the dwell times and the number of occurrences of these two vessels in more detail. Regarding Figure 2, it can be seen that these values are 3-4 times higher than the dwell times and the number of occurrences of the other vessels, and thus it can be easily concluded that these two vessels engaged in illegal activities until approximately the twentieth week.

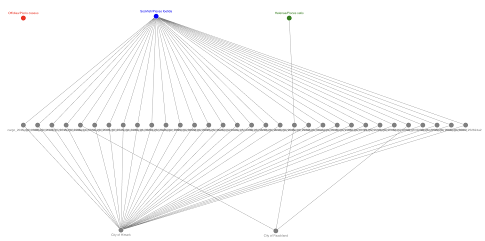
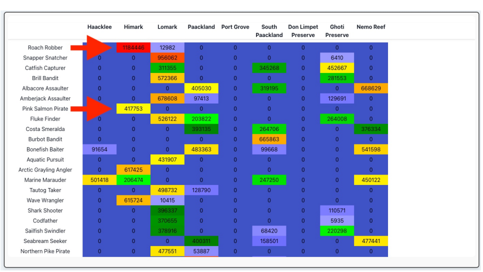


Figure 1: Cargo information of prohibited fish species and the cities they were taken to

3.2 Inappropriate Behavior of Fishing Vessels

The change in behavior of some other vessels after the vessels belonging to SouthSeafood Express Corp were caught (see Fig. 3) reveals that these vessels also engaged in inappropriate activity. If we examine these inappropriate activities in more detail: Figure 1 shows three different fish species that are only found in the ecological preserve area, meaning that hunting is prohibited. The cargo IDs of these fish and the harbors to which these cargoes go are shown in connection. Considering that the graph belongs to June, it is understood that some vessels continued their illegal activities after the capture of vessels belonging to SouthSeafood Express Corp. When the reports of the illegal activity vessels and the harbors to which the cargo went are examined and when the relevant vessel was found in the relevant harbors at that time, it can be easily concluded that several suspicious vessels were involved in illegal activities. When similar results are compared with the vessels whose behavior changed after the twentieth week in Figure 3, it becomes clear that the suspicious vessels found were involved in illegal activities.



	Haacklee	Himark	Lomark	Paackland	Port Grove	South Paackland	Don Limpet Preserve	Ghoti Preserve	Nemo Reef
Roach Robber	[illegible]	1184446	12982	0	0	0	0	0	0
Snapper Snatcher	0	0	956062	0	0	0	0	6410	0
Catfish Capturer	0	0	311355	0	0	345268	0	452667	0
Brill Bandit	0	0	572366	0	0	0	0	281553	0
Albacore Assaulter	0	0	0	405030	0	319195	0	0	668629
Amberjack Assaulter	0	0	678608	97413	0	0	0	129691	0
Pink Salmon Pirate	[illegible]	417753	0	0	0	0	0	0	0
Fluke Finder	0	0	526122	203822	0	0	0	264008	0
Costa Smeralda	0	0	0	393135	0	264706	0	0	376334
Burbot Bandit	0	0	0	0	0	665863	0	0	0
Bonefish Baiter	91654	0	0	483363	0	99668	0	0	541598
Aquatic Pursuit	0	0	431907	0	0	0	0	0	0
Arctic Grayling Angler	0	617425	0	0	0	0	0	0	0
Marine Marauder	501418	206474	0	0	0	247250	0	0	450122
Tautog Taker	0	0	498732	128790	0	0	0	0	0
Wave Wrangler	0	615724	10415	0	0	0	0	0	0
Shark Shooter	0	0	396337	0	0	0	0	110571	0
Codfather	0	0	370655	0	0	0	0	5935	0
Sailfish Swindler	0	0	378916	0	0	68420	0	220298	0
Seabream Seeker	0	0	0	400311	0	158501	0	0	477441
Northern Pike Pirate	0	0	477551	53887	0	0	0	0	0

Figure 2: Dwell duration of fishing vessels in cities and ecological preserves is shown in colors ranging from blue to red, considering their values

3.3 Fishing Activity Change After SouthSeafood Express Corp Was Caught

The pixel graph (see Fig. 3) was analyzed by finding vessels with a similar pattern of location visits by suspicious vessels. From week 5 to week 48, there was a remarkable change in the locations visited by other fishing vessels, as we can see from the Vessels and Locations pixel graph. After suspected vessels were caught Roach Robber and Snapper Snatcher, the dwell time and the occurrence of location counts changed significantly. Before the vessel were caught, Wrasse Beds, Nav C and Ghoti Preserve were frequently visited, indicating that these were likely hotspots for illegal activities. However, following the interception of the suspect vessels, there was a marked decrease in the frequency of visits to these locations. This suggests that illegal activities have been disrupted, leading to a change in vessel behavior.

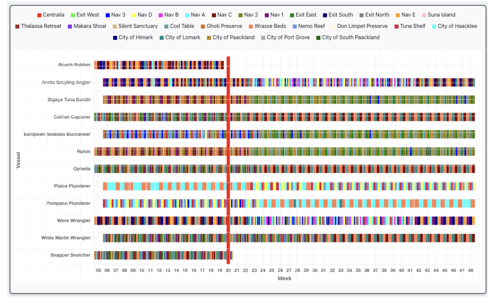


Figure 3: A weekly pixel graph of suspicious vessels and their locations is provided, where each color corresponds to a specific location, and the graph is generated based on the sequence in which these locations are visited

3.4 New Behaviors In The Oceanus Commercial Fishing Community

A significant increase in activity is observed at Nav 2 and East Exit (see Fig. 3). The increase in activity at these locations suggests that vessels may have redirected their activities to avoid detection or to adapt to the new enforcement environment. This change in behavior highlights the ability of vessels to adapt and the ongoing challenge of monitoring illegal fishing activities. Additionally, changes in location patterns emphasize the importance of continuous surveillance and dynamic enforcement strategies to effectively counter illegal fishing activities.

4 Conclusion

This study highlights the complex and interconnected nature of illegal fishing activities, identifying critical nodes based on the VAST Challenge 2024. By analyzing patterns associated with cargo IDs and their connections to fishing vessels across various locations, a comprehensive overview of the illegal fishing landscape was developed. This analysis not only identified vessels engaged in illegal activities but also revealed broader networks essential for targeted enforcement efforts, underscoring the need for an integrated approach to protect marine ecosystems and ensure sustainable fisheries management.

However, the approach has limitations, primarily relying on the availability and accuracy of cargo ID data, which may be incomplete or erroneous. Additionally, the methodology doesn't fully account for the dynamic nature of illegal fishing networks, which may evolve rapidly. Expanding the scope to include satellite imagery or AIS (Automatic Identification System) data could enhance the accuracy of the findings. To address these challenges, advanced data mining techniques could provide deeper insights. Anomaly detection can identify suspicious activities, while association rule mining can uncover relationships between events. Time-series analysis can capture trends over time, and cluster analysis can group similar patterns, enabling more targeted investigations.

References

[1] K. Healy and S. Reardon, "Visual Analytics: Combining Domain Expertise with Data Science to Address Complex Problems," in *Proc. SAS Global Forum*, 2015, Cary, NC, USA.

[2] D. Zissis, D. Lekkas, and C. Papadopoulou, "Graphical representation of fishing vessels with the state node circles and transition arcs," *ResearchGate*, 2014.