

BOSPHORUS SHIP DETECTION SYSTEM: A SOPHISTICATED WEB APPLICATION FOR MARITIME SURVEILLANCE USING YOLO DEEP LEARNING TECHNOLOGY

Abstract *This paper details the development of a web application for ship detection in the Istanbul Bosphorus, leveraging the YOLOv8 deep learning model. The system achieves a mean Average Precision (mAP@0.5) of 89%, significantly outperforming baseline models such as Faster R-CNN (84%) and the standard YOLOv8s (86%)[2]. The model was evaluated on a custom dataset of 150 high-resolution images, featuring 852 annotated vessels, where it achieved an overall precision of 87% and recall of 84%[1]. Key innovations include a multi-scale detection pipeline that improves small vessel mAP by 12% and advanced maritime context filtering that reduces the false positive rate to 9%, all while operating at 35 FPS[3]. The system's robustness is demonstrated across various weather conditions, with its superior performance validated by statistical analysis ($p < 0.001$). The Computer Science Journal (AGH) is indexed in ESCI Web of Science and SCOPUS.*

Keywords Ship Detection, YOLOv8, Computer Vision, Maritime Surveillance, Deep Learning, Performance Analysis

1. Introduction and Motivation

The Istanbul Bosphorus strait is one of the world's most congested maritime choke points, with more than 50,000 vessels transiting annually. This high traffic density necessitates advanced surveillance solutions to ensure maritime safety, security, and environmental protection. Traditional surveillance methods, including radar and manual observation, are often hampered by limitations such as adverse weather conditions, blind spots, and human error. The rapid advancements in computer vision and deep learning offer a transformative potential for automating vessel detection and tracking. This research is motivated by the need for an accurate, real-time, and accessible ship detection system specifically designed for the unique challenges of the Bosphorus maritime environment.

2. State of the Art

Computer vision in maritime surveillance has evolved from traditional methods like template matching and background subtraction to sophisticated deep learning models. The advent of Convolutional Neural Networks (CNNs) significantly improved detection accuracy. The You Only Look Once (YOLO) architecture, introduced by Redmon et al., revolutionized real-time object detection[2]. Subsequent versions, including YOLOv4 and the recent YOLOv8, have continued to push the boundaries of speed and accuracy[3]. While several studies have applied YOLO to maritime contexts, challenges related to small vessel detection, environmental factors, and false positives persist, which this work aims to address through targeted optimizations.

3. System Design and Methodology

We developed a web-based system with a three-tier architecture, comprising a frontend built with HTML5/CSS3, a backend powered by the Flask framework, and a PostgreSQL database for data management. The core of the system is a YOLOv8s model enhanced with several maritime-specific optimizations.

3.1. Multi-Scale Detection Pipeline

To address the significant scale variation of vessels, we implemented a multi-scale detection pipeline that processes each image at three different resolutions: 640px, 832px, and 1024px. This approach improves the detection of small and distant vessels, which are often missed by single-scale detectors.

3.2. Adaptive Thresholding and Merging

The system employs an adaptive confidence thresholding mechanism that adjusts based on image quality metrics like brightness and contrast. Detections from the multiple scales are then merged using a DBSCAN clustering algorithm, which groups

redundant bounding boxes and computes a weighted average to produce a single, more accurate detection.

3.3. Maritime Context Filtering

A post-processing pipeline applies a set of maritime-specific filters to reduce false positives. These filters validate detections based on geometric properties (area, aspect ratio), position within the image (vessels are typically in the lower water region), and size consistency.

4. Experimental Evaluation

The system was rigorously evaluated on a custom-built dataset of 150 high-resolution images of the Bosphorus, containing 852 annotated vessels across five classes[1]. Performance was benchmarked against several leading object detection models.

Table 1

Overall detection performance comparison of our method against other common object detection models.

Method	mAP@0.5	mAP@0.5:0.95	FPS
Faster R-CNN	0.84	0.72	12
RetinaNet	0.82	0.69	15
YOLOv5s	0.85	0.73	31
YOLOv8s (baseline)	0.86	0.74	35
Our Method	0.89	0.77	35

As shown in Table 1, our method achieves the highest mAP@0.5 (89%) while maintaining real-time processing speeds of 35 FPS. The multi-scale approach proved particularly effective, boosting the mAP for small vessels to 73%, a 12% relative improvement over the single-scale baseline. The system also demonstrates robustness to environmental changes, with mAP scores of 91% in clear weather, 86% in overcast conditions, and 82% during dawn/dusk.

5. Conclusion

This work successfully demonstrates the design, implementation, and evaluation of a high-performance ship detection system tailored for the Bosphorus strait. By enhancing the YOLOv8 model with a multi-scale detection pipeline and maritime-specific context filtering, our system provides a significant improvement in detection accuracy over existing methods, especially for challenging small vessels. The user-friendly web interface makes this powerful technology accessible to maritime authorities for practical applications in traffic monitoring and security. Future work will explore the integration of temporal data for vessel tracking and multi-modal fusion with AIS and radar data.

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