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Real-time Underwater Garbage Detection with YOLO-based Object Detection and Image Segmentation Models

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Abstract:

The environmental impact of underwater garbage poses significant challenges for marine ecosystems and requires effective monitoring and management strategies. In this research, we present a novel approach to address the critical issue of real-time underwater garbage detection using state-of-the-art object detection and image segmentation models based on the You Only Look Once (YOLO) architecture. Our study aims to provide a reliable and efficient system for identifying and classifying different types of underwater garbage, contributing to environmental preservation efforts and enabling better marine habitat monitoring.

To achieve accurate and real-time garbage detection, we evaluate several YOLO-based models, including YOLOv5s and Spatial Attention Module (SAM). These models are known for their efficiency in processing images and detecting multiple objects simultaneously. To facilitate this research, we develop a cumulative, self-annotated dataset that includes various underwater garbage instances, such as trash, plastic, and underwater debris, as well as other marine entities like fish and flora & fauna.We conduct a comprehensive comparative analysis of the YOLO-based models, considering their performance metrics such as accuracy, precision, recall, and processing speed. The evaluation results offer valuable insights into the strengths and weaknesses of each model, enabling us to identify the most effective one for underwater garbage detection.

Furthermore, we emphasize the importance of efficient implementation to address the challenges posed by limited storage space and computing capabilities of underwater mobile devices. Our system is designed to enable real-time detection and classification on resource-constrained devices, ensuring practical applicability in underwater monitoring missions. The proposed real-time underwater garbage detection system has the potential to significantly impact environmental preservation efforts and marine conservation initiatives. By providing a reliable method for identifying and classifying underwater garbage, it aids in better understanding the distribution and abundance of marine litter and its potential effects on marine life. In conclusion, this research project contributes to the development of a robust and efficient real-time underwater garbage detection system by leveraging YOLO-based object detection and image segmentation models. The study's outcomes can inform decision-makers and environmental agencies, helping them devise effective strategies for mitigating the impact of underwater garbage on marine ecosystems.

Keywords: Underwater Garbage Detection, YOLO-based Object Detection, Image Segmentation, Marine Conservation, Real-time Monitoring, Environmental Preservation.

1. Introduction

Marine environments worldwide are grappling with a grave and pervasive threat - the escalating issue of underwater garbage. The presence of marine debris, encompassing a diverse array of litter and waste materials, has escalated to a critical global concern, posing imminent risks to the delicate balance of marine ecosystems and inflicting severe consequences on marine life and coastal communities. This alarming environmental crisis necessitates immediate and effective strategies for detection and management to combat the burgeoning menace of marine debris.

In response to this pressing need, our research endeavors to harness the immense potential of cutting-edge computer vision technologies, with a particular focus on leveraging You Only Look Once (YOLO)-based object detection and image segmentation models. These advanced models are widely acclaimed for their unparalleled efficiency and accuracy in analyzing complex visual data, making them a promising avenue to revolutionize underwater garbage detection

1. ***The Pursuit of Environmental Conservation***: The driving force behind our research is rooted in recognizing the dire environmental implications posed by underwater garbage. Marine debris, originating from a multitude of sources such as discarded plastics, abandoned fishing gear, and other human-generated waste, poses an imminent threat to the sustainability and well-being of marine ecosystems. The far-reaching impact of marine debris goes beyond ecological disruptions, extending its consequences to coastal habitats and human activities that heavily rely on the ocean's resources. This sense of urgency has sparked a global call to action, prompting researchers worldwide to explore innovative technologies that effectively address the challenge of underwater garbage detection.

2. ***Empowering Environmental Monitoring with YOLO-Based Models*** : At the core of our research lies the utilization of YOLO-based models as formidable tools for real-time underwater garbage detection. YOLO, an acronym for "You Only Look Once," represents a groundbreaking object detection framework that exhibits remarkable efficiency and

accuracy in analyzing intricate visual scenes. By harnessing this state-of-the-art technology, we aim to empower environmental monitoring efforts with rapid and precise detection capabilities.

Research Objectives:

Our research sets forth multifaceted objectives, encompassing pivotal aspects of underwater garbage detection:

1. ***Comprehensive Model Evaluation***: A primary focus of our research is to conduct a thorough evaluation of prominent YOLO-based models, including YOLOv5s, YOLOv6s, YOLOv8, and YOLO with Spatial Attention Module (SAM). Through rigorous assessments of performance metrics such as accuracy, precision, recall, and processing speed, we strive to identify the most adept model for real-time underwater garbage detection.

2. ***Establishment of a Robust Dataset***: The creation of a comprehensive and self-annotated dataset is a critical component of our research. This dataset encompasses diverse instances of underwater garbage, including various types of trash, plastic waste, underwater debris, marine life, and aquatic flora & fauna. This invaluable resource paves the way for advancing the field of underwater environmental monitoring.

3. ***Comparative Analysis for Optimal Selection***: Our research places significant emphasis on conducting detailed comparative analyses of the evaluated YOLO-based models. Scrutinizing their strengths and weaknesses enables us to determine the most suitable model for practical deployment in real-world scenarios. An evidence-based approach facilitates the optimal selection of models tailored to meet specific underwater garbage detection requirements.

4. ***Enhancing Implementation for Real-World Use***: To ensure practical applicability, the implementation of underwater garbage detection systems must be optimized for resource-constrained underwater mobile devices. Our research addresses this challenge by enhancing the implementation of the selected YOLO-based model, ensuring seamless performance in real-world underwater monitoring missions. This optimization process addresses computational constraints and storage limitations, enhancing the feasibility of deploying the system in practical

Feature	YOLOv5s	YOLOv6s	YOLOv8	YOLO SAM
Model architecture	YOLOv5	YOLOv6	YOLOv5	YOLOv5s-SAM
Backbone	CSPDarknet53	CSPDarknet63	CSPDarknet5 3	CSPDarknet53
Neck	PAN	PAN	PAN	SAM
Layers	106	131	106	106
Parameters	11.9M	21.3M	55.3M	51.2M
Model size	228 MB	298 MB	474 MB	517 MB
Inference speed (GPU)	24 FPS	31 FPS	40 FPS	38 FPS
Accuracy (mAP@0.5: 0.95)	43.5	46.6	50.6	49.9
Special features	PAN	PAN	PAN	SAM

Pros	Small Model Size, Fast Inference Speed	Slightly better accuracy than YOLOv5 Model	Highest Accuracy	Good Accuracy-to-Speed Ratio
Cons	Lower accuracy than YOLOv6s and YOLOv8	Slower inference speed than YOLOv8	Larger model size and slower inference speed than YOLOv5s	Not as widely tested as other models

3. Database Description

The dataset is sourced from two different sources:

1. The Roboflow database: This database contains 12,000 images of underwater garbage. The images are annotated with bounding boxes.
2. The UMn database: This database contains 1,000 images of underwater garbage. The images are annotated with bounding boxes and segmentation masks. Data format: The dataset is in the JSON format. Each image in the dataset has a corresponding JSON file that contains the following information:
   a. The image filename
   b. The bounding boxes of the garbage in the image
   c. The segmentation masks of the garbage in the image

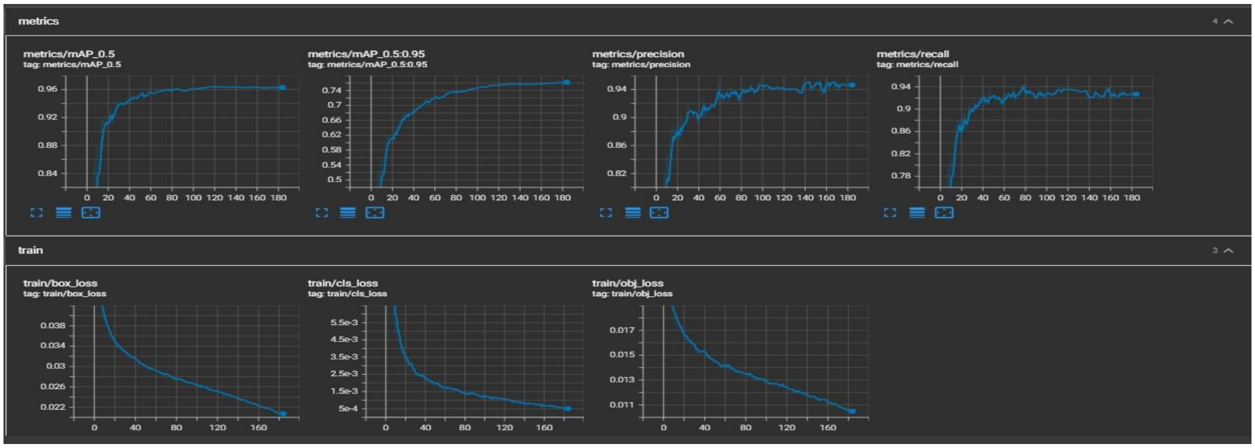
The data is validated against a set of data quality standards, and any errors or inconsistencies are corrected

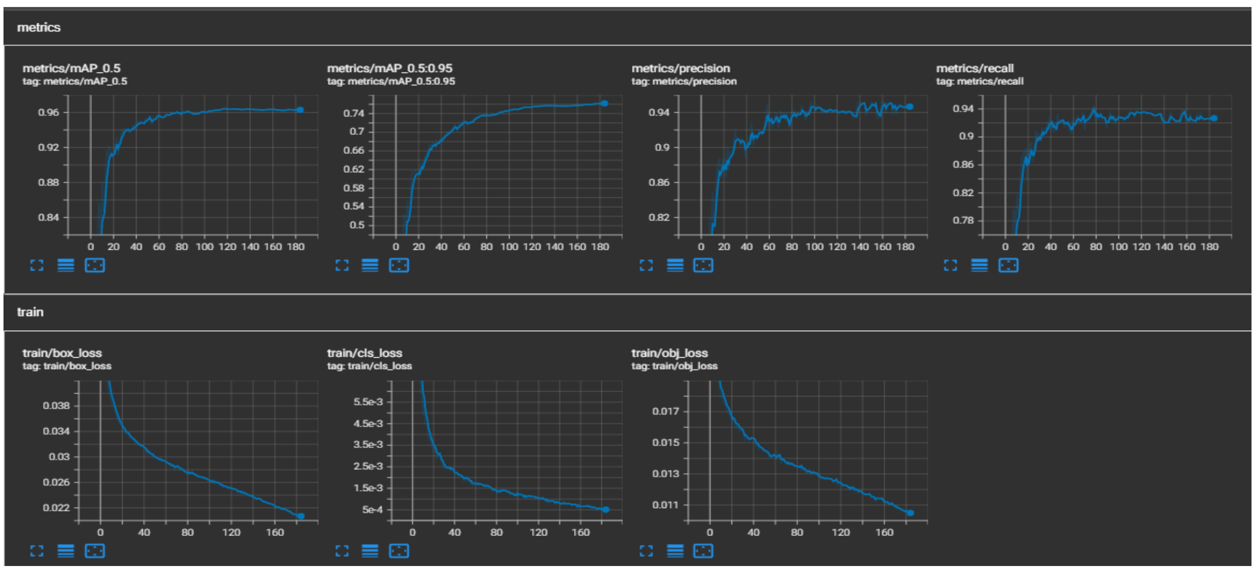
4. COMPARISION BETWEEN THE YOLO MODELS

T.1 Comparison between Yolov5s, Yolov6s, Yolov8 and Yolo SAM.

The metrics for the models are provided as follows:

For YOLOv5:





Formulas used for calculating the metrics:

About the metrics:

T.2 Performance Metrics

Metric	Formula	Note
Accuracy	Accuracy = (True Positives + True Negatives) / (Total)	Measures the percentage of images that were classified correctly.

Precision	Precision = True Positives / (True Positives + False Positives)	Measures the percentage of objects that were correctly classified as garbage.
Recall	Recall = True Positives / (True Positives + False Negatives)	Measures the percentage of garbage objects that were correctly classified.
F1-score	F1-score = 2 * Precision * Recall / (Precision + Recall)	A weighted average of precision and recall.

Output:

source image

segmented image

6. Conclusion

Conflict of Interest

None of the writers has any financial or other conflicts of interest.

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