IOT BASED UNDER WATER OBJECT DETECTION

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College	:	*Bangalore Institute Of Technology, Bengaluru*
Branch	:	*Electronics And Communication Engineering*
Guide(S)	:	*Prof Swathi* *Dr. S L Mukthi*
Student(S)	:	*Ms. Nidhi V* *Ms. Pooja B M* *Ms. Pooja Mahesh Gangnaik* *Ms. Prakruthi G*

Keywords:

IoT-Based Underwater Monitoring, Underwater Object Detection, Machine Learning, Computer Vision, YOLO Algorithm, Raspberry Pi, Edge Computing, OpenCV, Marine Debris Detection, ESP32 Communication, Wireless IoT Protocols.

Introduction:

Underwater environments contain valuable biological, ecological, and structural information that is difficult to monitor due to limited visibility, high operational costs, and restricted accessibility. Traditional methods such as manual inspection by divers or the use of expensive underwater robotic systems are time-consuming, risky, and not suitable for continuous monitoring. These limitations highlight the need for an efficient, automated, and cost-effective solution for underwater observation.

With recent advancements in Internet of Things (IoT), embedded systems, and machine learning, it has become possible to develop intelligent systems capable of real-time data processing and remote monitoring. This project proposes an IoT-based underwater object detection system that utilizes a waterproof camera and Raspberry Pi for capturing and processing underwater visuals. The system employs computer vision techniques and a YOLO-based machine learning model to accurately detect and classify objects such as marine debris, aquatic species, and submerged structures.

The detected information is transmitted wirelessly using IoT communication protocols, enabling remote monitoring through a user interface. This approach ensures continuous observation without human intervention, making it suitable for applications such as marine research, environmental monitoring, pollution detection, and underwater exploration. The proposed system aims to provide a scalable, reliable, and low-cost solution for real-time underwater surveillance while contributing to environmental sustainability and technological advancement.

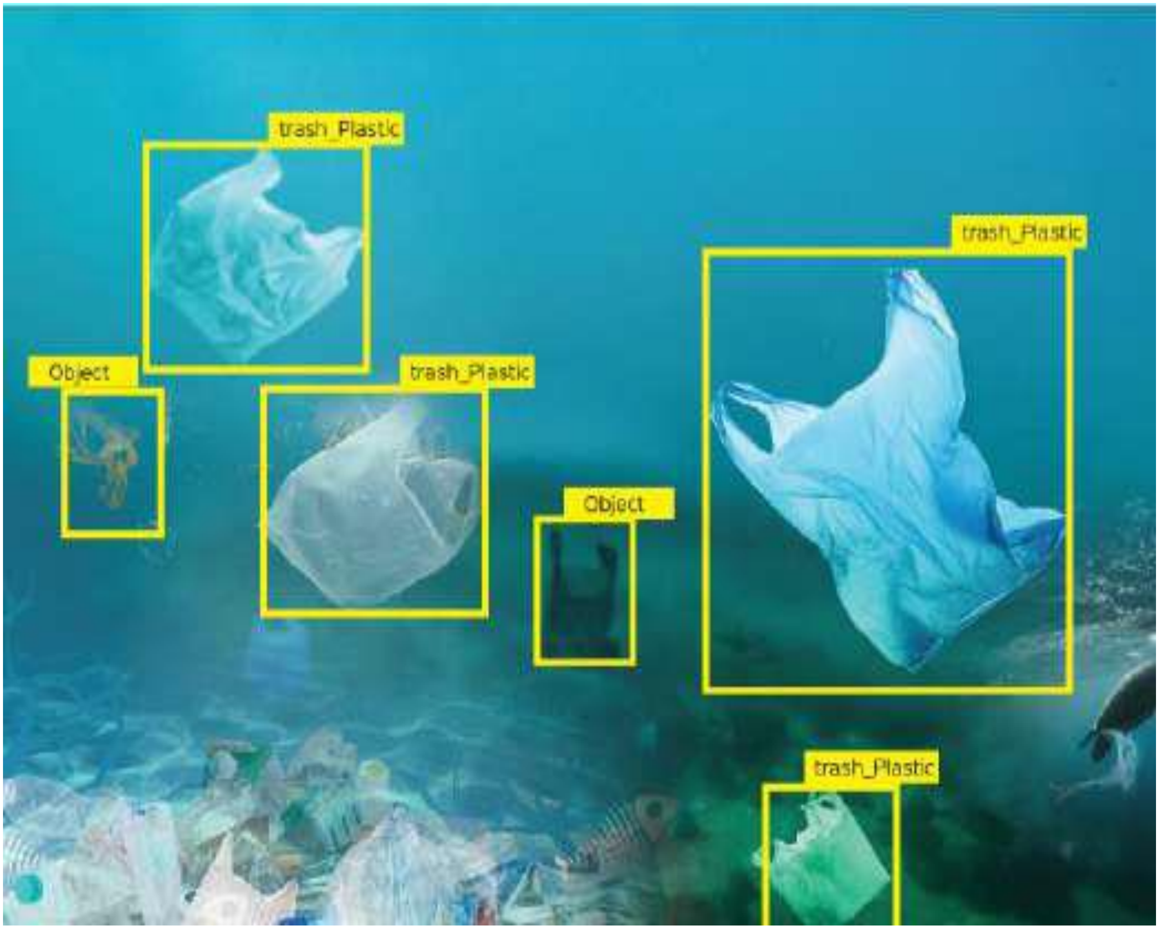


Figure 1: Detection of marine debris and plastic waste using YOLO-based underwater object detection

Objectives:

1. To design and develop an IoT-based underwater object detection system using a waterproof camera and Raspberry Pi for real-time monitoring.
2. To implement machine learning and computer vision algorithms capable of identifying underwater objects with reliable accuracy.
3. To enable wireless data transmission of detection results using IoT communication protocols for remote visualization and monitoring.
4. To evaluate and analyze system performance under different underwater conditions such as lighting, water clarity, and object distance.

Methodology:

1. The system follows a structured workflow starting from dataset preparation and model training to real-time detection using Raspberry Pi and IoT-based monitoring.
2. Underwater images/videos are collected and annotated using Label Studio to create a high-quality labelled dataset.
3. A machine learning model (YOLO Lightweight variant) is trained using annotated data and then deployed on Raspberry Pi for real-time inference.
4. Detection results are transmitted wirelessly to a remote dashboard using IoT communication protocols such as MQTT/HTTP.

Techniques / Tools Used:

1. Label Studio for annotation
2. YOLO-based object detection model
3. Raspberry Pi with waterproof camera
4. Python, OpenCV (frame handling), and MQTT/HTTP
5. Remote monitoring dashboard/UI

Step-by-Step Workflow:

1. **Dataset Creation**
   Underwater images/videos used as raw input for the system.
2. **Annotation Using Label Studio**
   Objects are labelled (fish, debris, coral, etc.) to prepare training data.
3. **Model Training**
   YOLO model is trained and fine-tuned on the labelled dataset for underwater object recognition.
4. **Model Deployment on Raspberry Pi**
   Exported model (YOLO format) deployed on Raspberry Pi with camera input.
5. **Real-Time Object Detection**
   Raspberry Pi captures live video and runs inference to detect underwater objects.
6. **IoT Data Transmission**
   Detected objects, timestamps, and related metadata sent wirelessly to a remote interface.
7. **Monitoring & Analysis**
   Users monitor detected objects through a dashboard or local display for research and decision-making.

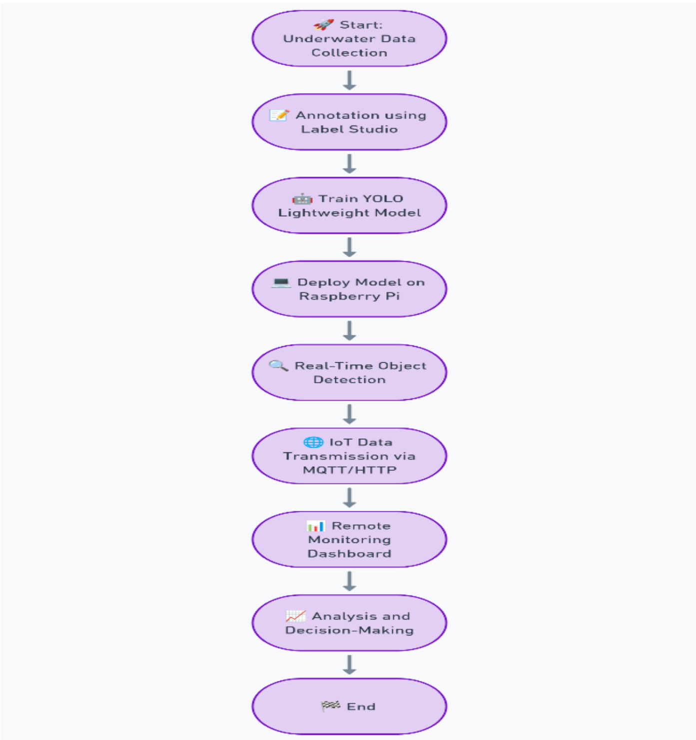
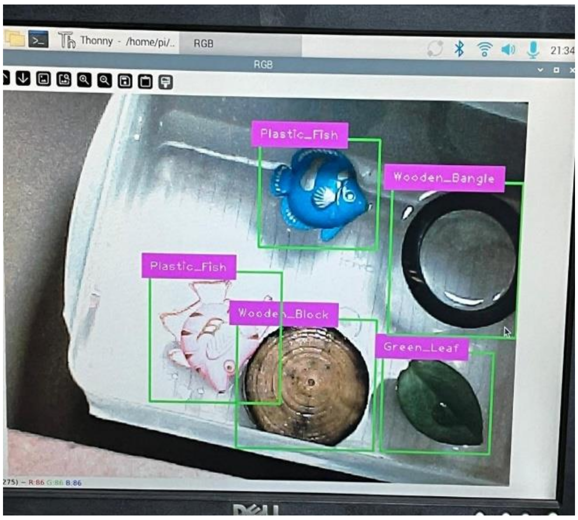


Figure 2: Flowchart of the model

Result and Conclusion:

In conclusion, the system successfully detected underwater objects using a trained YOLO model deployed on a Raspberry Pi. The live detection results were displayed on both the monitor and LCD, confirming proper model deployment and IoT-based feedback functionality. The detection accuracy improved with dataset annotation and model fine-tuning, demonstrating reliable performance under controlled underwater conditions. Additionally, the system achieved real-time response with minimal delay, indicating efficient edge processing and seamless communication between Raspberry Pi and ESP32.



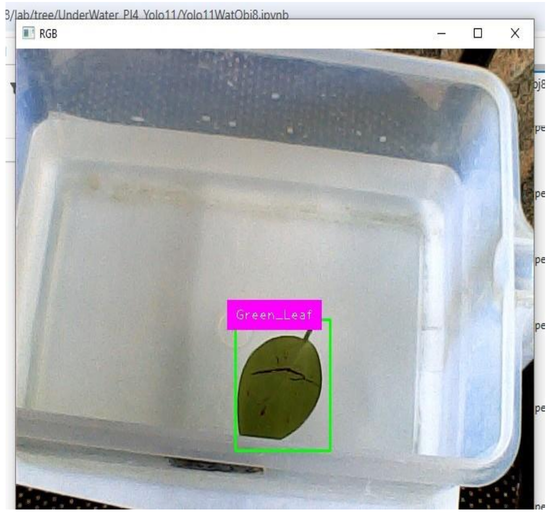


Figure 3 & *4:* Result, Multiple Objects and Single Object Detected

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Future Scope:

The future scope of this project includes:

1. Performance Improvements: Accuracy can be further enhanced by expanding the dataset, improving visibility compensation, and optimizing detection in low-light or high-turbidity underwater conditions.

2. Integration With Advanced Technologies: Future versions can integrate sonar, underwater drones, cloud computing, and AI-based object tracking to improve automation and reliability.
3. Scalability and Real-Time Deployment: The system can be deployed at a larger scale in oceans, rivers, fish farms, ports, and industrial underwater inspections with live remote monitoring.
4. Cross-Domain Applications: The system can be extended for marine archaeology, rescue operations, aquaculture automation, and autonomous underwater vehicle navigation.
5. Human Detection Capability: With further model training, the system can also detect divers or humans underwater for safety, rescue, and surveillance applications.