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AquaSense AI: IoT-Enabled Robotic System for Smart Lake Cleaning

J Ryan Elijah[1], S Chris Jacques[2] and Pearly Princess[3]
[1-3]Karunya Institute of Technology and Sciences, Coimbatore, India
Email: ryanelijah@karunya.edu.in, chrisjacques@karunya.edu.in, pearlyprinces@karunya.edu

***Abstract*— Water pollution due to floating waste accumulation in lakes has become a critical environmental issue affecting aquatic ecosystems and public health. Traditional monitoring and cleaning methods are manual, inefficient, and unsuitable for large-scale continuous operation. This paper presents AquaSense AI, an IoT-enabled robotic system for automated lake waste detection and classification. The system integrates a camera-based vision module with a YOLO deep learning model for real-time object detection and classification of waste into biodegradable and non-biodegradable categories. An ESP32-based embedded system enables data transmission to a cloud platform for remote monitoring using IoT. The proposed system improves detection speed, reduces human effort, and enables continuous monitoring. Experimental results demonstrate reliable detection performance and real-time communication, making it a scalable solution for smart environmental management.**

***Index Terms*— IoT, YOLO, Waste Detection, Smart Lake, Computer Vision, ESP32, Blynk.**

I. INTRODUCTION

Water pollution in lakes caused by floating waste such as plastics, organic matter, and pollutants has become a significant environmental challenge. Traditional monitoring systems rely on manual inspection and periodic cleaning, which are inefficient, labor-intensive, and lack scalability.

Recent advancements in Artificial Intelligence (AI), Internet of Things (IoT), and Computer Vision enable the development of automated monitoring systems. This paper proposes an intelligent system capable of detecting and classifying waste in real-time using deep learning and IoT integration.

The objective of this work is to design a system that:

- Detects lake waste automatically
- Classifies waste using computer vision
- Enables real-time monitoring through IoT
- Reduces human intervention

II. RELATED WORK

Existing systems for waste detection primarily use image processing and Convolutional Neural Networks (CNNs). While CNNs are effective for feature extraction, they often fail to handle complex environmental conditions such as reflections and water disturbances.

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YOLO (You Only Look Once) has emerged as a powerful real-time object detection algorithm with high speed and accuracy. Several studies demonstrate YOLO's effectiveness in environmental monitoring applications. However, existing solutions lack:

- Real-time IoT integration
- Automated monitoring capabilities
- Scalable deployment for large water bodies

This work addresses these gaps using a combined YOLO + IoT approach.

III. Proposed System

The proposed system integrates computer vision with IoT for automated lake waste detection.

System Overview

The system consists of:

- Image acquisition module (webcam/camera)
- Preprocessing module
- YOLO object detection model
- ESP32 microcontroller
- IoT cloud platform (Blynk)

Working Principle

- Images are captured from the lake surface
- Images are preprocessed (resizing, normalization)
- YOLO detects waste objects
- Waste is classified into:
    - Biodegradable
    - Non-biodegradable
- Results are transmitted to the cloud via ESP32

This architecture enables real-time detection and remote monitoring.

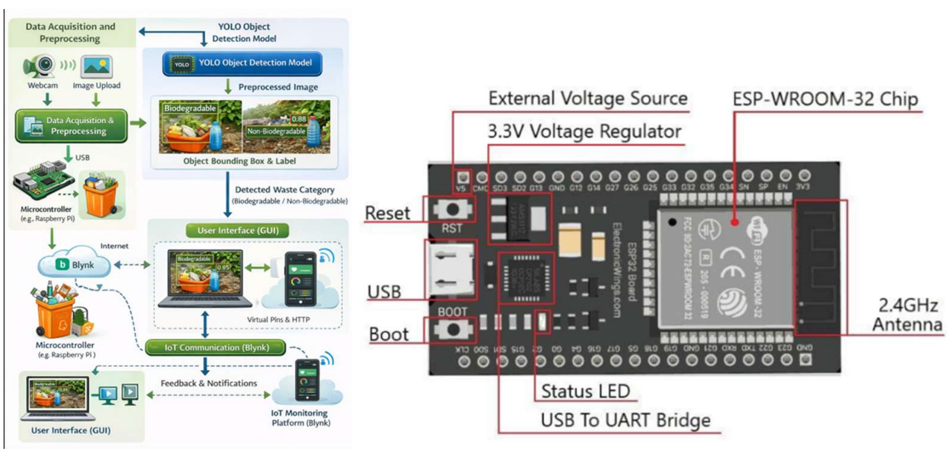

Figure 1

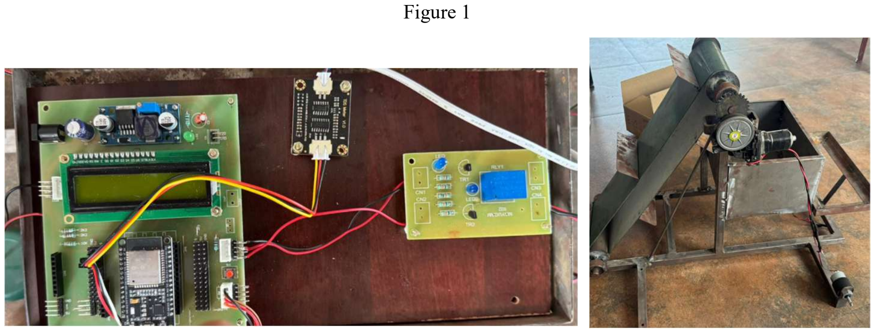

Figure 2

IV. Methodology

The workflow of the system consists of the following steps:
Step 1: Image Acquisition
Images are captured using a webcam or uploaded manually.
Step 2: Preprocessing

- Image resizing
- Noise reduction
- Normalization

Step 3: Object Detection
YOLO processes the image and:

- Detects waste objects
- Generates bounding boxes
- Assigns confidence scores

Step 4: Waste Classification
Objects are classified into:

- Biodegradable waste
- Non-biodegradable waste

Step 5: Visualization
Bounding boxes with labels are displayed on the GUI.
Step 6: IoT Communication
Results are sent to the Blynk cloud using ESP32 for real-time monitoring.

V. Implementation

Hardware Components

- ESP32 microcontroller
- Camera module
- Ultrasonic sensor
- Relay module
- Motors

Software Components

- Python (YOLO model)
- OpenCV (image processing)
- Arduino IDE (ESP32 programming)
- Blynk IoT platform

System Integration

- ESP32 reads sensor data and controls hardware
- YOLO processes images on system
- Data is transmitted to cloud via Wi-Fi

The system supports real-time operation and remote monitoring.

VI. Results and Discussion

The system was tested using real-time webcam input and sample images.
Observations

- YOLO successfully detected waste objects
- Accurate classification into biodegradable and non-biodegradable categories
- Real-time bounding box visualization achieved

Performance

- Fast detection suitable for real-time applications
- Reliable IoT communication with minimal delay
- System operates continuously without manual intervention

Advantages

- Reduces human effort
- Enables continuous monitoring
- Scalable for large environments

Limitations

- Performance affected by poor lighting conditions
- Requires trained dataset for higher accuracy

VII. CONCLUSION

This paper presented AquaSense AI, an IoT-enabled intelligent system for automated lake waste detection and monitoring. The integration of YOLO-based object detection with ESP32 and IoT cloud enables real-time classification and remote monitoring. The system improves efficiency, reduces manual effort, and provides a scalable solution for environmental management.

Future work includes:

- Improving model accuracy with larger datasets
- Adding autonomous navigation
- Integrating mobile applications for control

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