

AUTOMATED WATER SURFACE CLEANER USING REAL-TIME OBJECT DETECTION AND IoT MONITORING

M Harsha Vardhan

Department of Mechanical Engineering, MVGR College of Engineering, Vizianagaram, Andhra Pradesh, India

Abstract - Water pollution caused by floating waste materials such as plastics, leaves, biomedical waste, and domestic garbage has become a major environmental concern across rivers, lakes, and ponds. Conventional cleaning techniques mainly depend on manual labor, which is time-consuming, inefficient, and unsafe in highly polluted environments. To address these challenges, this paper presents the design and development of an Automated Water Surface Cleaner integrated with real-time object detection and IoT-based monitoring. The proposed system utilizes Raspberry Pi 4, TensorFlow Lite-based object detection, ultrasonic sensors, conveyor belt mechanisms, and DC motor-driven propellers for autonomous waste collection. A camera module continuously captures live video streams to identify floating waste objects and initiate the cleaning process automatically. The system also integrates IoT functionality through the Blynk platform for remote monitoring and operational control. The developed prototype demonstrates efficient floating waste detection with an average accuracy of 92% while maintaining low power consumption and reduced human intervention. The proposed system offers a cost-effective, scalable, and environmentally sustainable solution for automated cleaning of small and medium-sized water bodies. Future improvements may include GPS-based navigation, solar-powered operation, and cloud-based analytics for large-scale deployment.

Key Words: Automated Water Surface Cleaner, Raspberry Pi, TensorFlow Lite, Object Detection, IoT Monitoring, Conveyor Belt Mechanism, Water Pollution, Autonomous Cleaning

1. INTRODUCTION

Water is one of the most essential natural resources for sustaining life on Earth. However, rapid industrialization, urbanization, population growth, and improper waste disposal practices have significantly increased water pollution levels worldwide. Floating waste materials such as plastics, leaves, domestic waste, and biomedical waste negatively impact aquatic ecosystems, reduce water quality, and threaten marine life.

Traditional cleaning methods for water bodies rely heavily on manual labor and mechanical collection systems, which are expensive, inefficient, and hazardous in contaminated environments. Recent advancements in automation, artificial intelligence, and IoT technologies have enabled the development of intelligent autonomous systems capable of

performing cleaning operations with minimal human intervention.

The proposed Automated Water Surface Cleaner combines object detection, embedded systems, and autonomous cleaning mechanisms to efficiently collect floating waste from water bodies. The system uses a Raspberry Pi-based control architecture integrated with ultrasonic sensors, a Pi camera module, and a conveyor belt mechanism to detect and remove waste materials automatically.

The major objectives of this project include:

- Reducing water pollution through autonomous waste collection.
- Minimizing human effort and operational risks.
- Improving cleaning efficiency using AI-based object detection.
- Providing a low-cost and scalable solution for water body maintenance

1.1 Literature Review

Several researchers have proposed automated systems for water cleaning applications. Mukhtar et al. developed a River Trash Collector System utilizing ballast tank mechanisms for floating waste collection. However, the design suffered from limited mobility and high manufacturing costs.

Chen Su et al. proposed an autonomous cleaning ship integrated with ultrasonic sensors for obstacle detection and navigation. Although the system demonstrated autonomous operation, its movement algorithm lacked optimization. Akash Sinha et al. introduced "Ro-boat," which utilized computer vision and robotic arm mechanisms for garbage collection. While effective in detection, the robotic arm increased overall energy consumption and system complexity.

Albitar et al. developed an underwater cleaning robot using flexible crawling mechanisms for submerged surface cleaning applications. Although suitable for underwater cleaning, the system required multiple active degrees of freedom, increasing complexity.

Recent studies have also explored IoT-based monitoring, AI-driven waste classification, and conveyor belt-based cleaning systems. However, most existing systems suffer from high costs, limited scalability, reduced processing efficiency, or lack of real-time monitoring capabilities.

1.2 Research Gaps

Despite considerable advancements in automated cleaning systems, several research challenges still remain unresolved:

[1] A. Limited Autonomous Navigation

Most existing systems lack intelligent navigation and optimized path planning mechanisms.

[2] B. Real-Time Processing Constraints

Embedded systems such as Raspberry Pi experience limitations while processing high-resolution live video streams.

[3] C. Multi-Object Waste Classification

Current models detect waste objects but fail to categorize waste types effectively.

[4] D. Lack of IoT-Based Analytics

Most systems do not support cloud-based monitoring or real-time data logging.

[5] E. Energy Optimization

Conventional systems utilize fixed motor speeds without adaptive power management techniques.

[6] F. Sustainable Power Management

Limited integration of renewable energy systems restricts operational autonomy

1.3 Research Gaps

The primary objectives of the proposed system are:

- To implement real-time floating waste detection using TensorFlow Lite.
- To automate waste collection using conveyor belt mechanisms.
- To integrate IoT-based monitoring and remote control.
- To reduce human effort and cleaning time.
- To improve sustainability through low-power operation.

2. MATERIALS AND METHODOLOGY

2.1 System Overview

The proposed Automated Water Surface Cleaner consists of:

- Raspberry Pi 4
- Pi Camera Module
- Ultrasonic Sensors
- Conveyor Belt Mechanism
- DC Motors and Propellers
- Motor Driver Modules
- IoT Monitoring Platform

The overall system continuously monitors the water surface using the Pi camera module. Once floating waste is detected, the conveyor belt mechanism activates automatically to collect and transfer the waste into a storage container.

2.2 Process Flow

The working process of the system is summarized as follows:

1. Robot initialization.
2. Obstacle detection using ultrasonic sensors.
3. Image capture through Pi camera.
4. Real-time object detection using TensorFlow Lite.
5. Classification of waste objects.
6. Conveyor belt activation for waste collection.
7. Continuous trajectory-based movement.

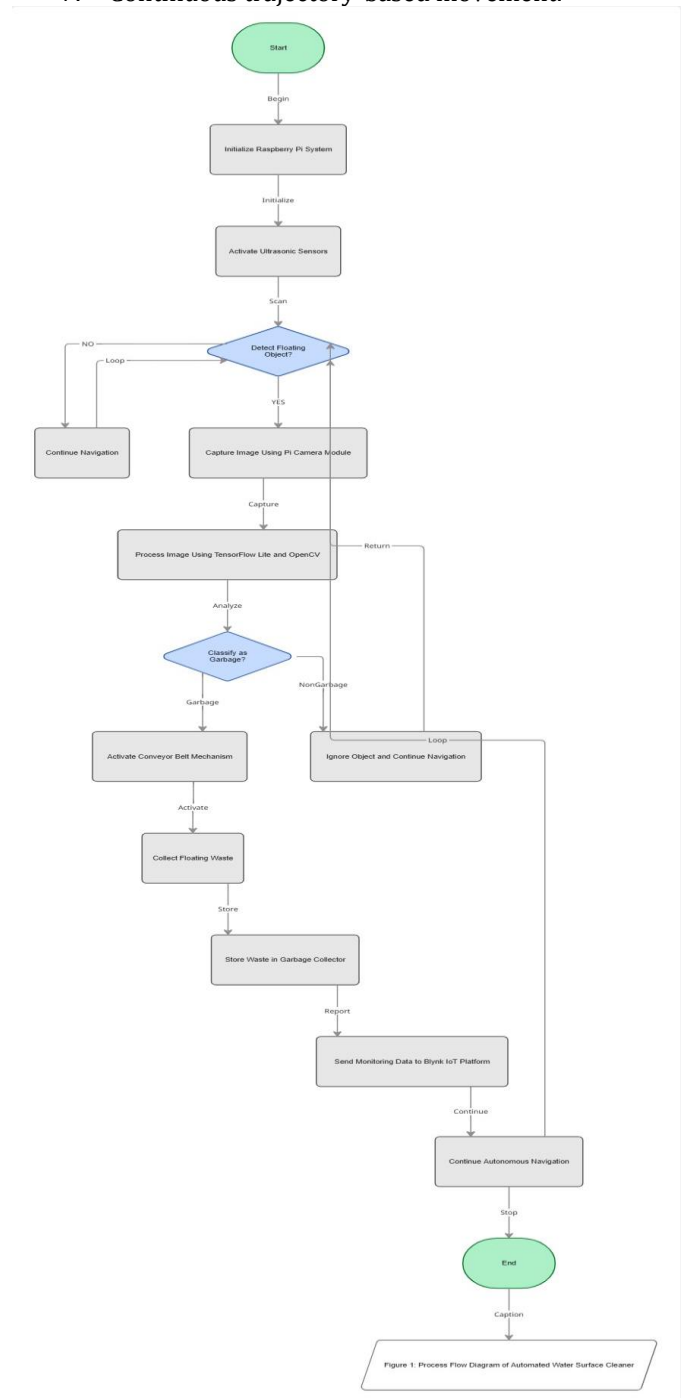


Figure 1: Process Flow Diagram of Automated Water Surface Cleaner

2.3 Mechanical Design

The robot chassis is fabricated using lightweight aluminum material to minimize drag and improve buoyancy. The conveyor belt mechanism uses rubber material with extruded ledges for efficient garbage collection.

The system includes:

- Two DC motors for conveyor operation
- Dual propeller mechanism for movement
- Floating garbage collector box
- Stabilized electrical compartment

The waste collector can hold approximately 1–3 kg of floating debris in a single cycle.

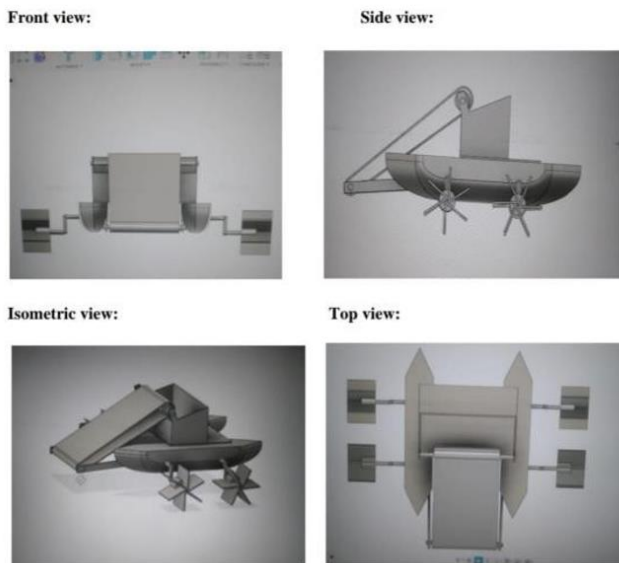


Figure 2: Mechanical Design and Isometric View of the Robot

2.4 Electronic Circuit Design

Raspberry Pi 4 acts as the master controller of the system. It communicates with motor drivers, sensors, and the camera module to execute cleaning operations.

The motor drivers control:

- Forward and reverse movement
- Conveyor belt operation
- Left and right navigation

The control system also supports autonomous trajectory movement and obstacle avoidance.

Electronic Circuit Diagram of the Proposed Automated Water Surface Cleaner System

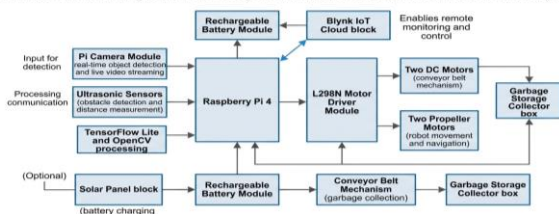


Figure 3: Electronic Circuit Diagram of the Proposed System

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2.5 Computer Vision and Object Detection

The proposed system uses TensorFlow Lite integrated with OpenCV for object detection and classification. The model processes real-time video streams captured by the Pi camera module.

The object detection algorithm:

- Identifies floating waste objects
- Draws bounding boxes around detected objects
- Classifies garbage types using trained COCO datasets

The implemented system achieved efficient real-time performance with acceptable detection accuracy.

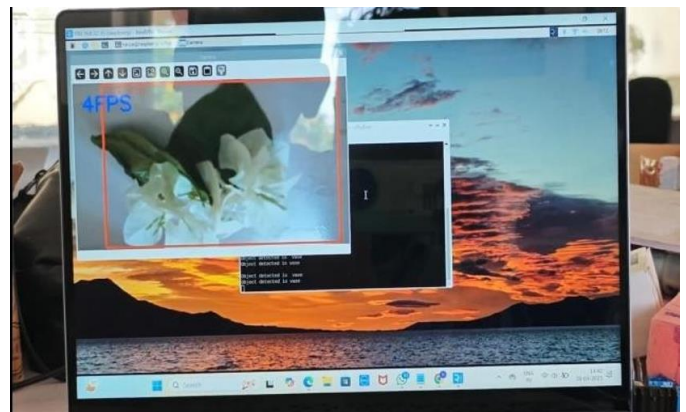


Figure 4: Real-Time Object Detection Results

3. RESULTS AND DISCUSSION

3.1 Object Detection Performance

The TensorFlow Lite model achieved an average detection accuracy of approximately 92% during experimental testing.

- **Observations**
- Real-time processing speed ranged between 4–9 FPS.
- Plastic and paper waste achieved higher detection accuracy.
- Floating leaves occasionally generated false-positive detections.
- **Improvements**
- Edge AI accelerators such as NVIDIA Jetson Nano can improve processing speed.
- Advanced CNN models may further enhance classification accuracy.

3.2 Cleaning Efficiency

The conveyor belt mechanism demonstrated efficient floating waste collection under various environmental conditions.

- **Performance Outcomes**
- Stable waste collection in stagnant water bodies.
- Efficient propeller-based navigation.
- Low power consumption during operation.

- **Optimization Strategies**
- Adaptive motor speed control using PWM.
- Integration of brushless DC motors for improved efficiency

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3.3 IoT Monitoring Performance

The Blynk IoT platform enabled:

- Real-time monitoring
- Remote motor control
- Battery status tracking

The system demonstrated reliable remote communication with minimal latency.

3.4 Energy Consumption Analysis

Battery-powered operation supported continuous cleaning for approximately 6–10 hours depending on motor usage conditions.

Future enhancements may include:

- Solar-powered charging systems
- MPPT-based battery management
- Low-power embedded controllers

4. DISCUSSION

The developed Automated Water Surface Cleaner successfully integrates AI-based object detection, IoT connectivity, and autonomous cleaning mechanisms into a single low-cost platform.

The proposed system demonstrates:

- High object detection accuracy
- Reduced operational cost
- Minimal human intervention
- Improved cleaning efficiency

However, further improvements are necessary for large-scale deployment, including:

- GPS-based navigation
- AI-driven route optimization
- Cloud-based monitoring systems
- Multi-object waste classification

The system also supports Sustainable Development Goals (SDGs) related to clean water, smart cities, and environmental sustainability.

5. CONCLUSION

This paper presented the design and implementation of an Automated Water Surface Cleaner integrated with real-time object detection and IoT monitoring capabilities. The proposed system effectively detects and removes floating waste materials using TensorFlow Lite-based computer vision and conveyor belt mechanisms.

Experimental analysis demonstrated reliable performance in terms of object detection accuracy, waste collection efficiency, and remote monitoring functionality. The developed system provides a cost-effective and scalable solution for cleaning rivers, ponds, and lakes while reducing environmental pollution and human effort.

Future work will focus on:

- GPS-assisted autonomous navigation
- Solar-powered operation
- Cloud-based analytics
- Advanced deep learning models
- Large-scale deployment in flowing water bodies

The proposed system represents a significant step toward sustainable and intelligent environmental cleaning technologies.

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