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Roboclean: Automated Garbage Collection With Conveyor Mechanism

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Abstract- — Increasing water pollution due to floating solid waste in rivers, lakes, and drainage canals has become a major environmental concern, and manual waste collection in water bodies is inefficient, unsafe, and time-consuming. This project presents Roboclean, an ESP32-based automated garbage collection system designed specifically for collecting floating waste from water surfaces using a conveyor belt mechanism. The system employs dual conveyor belts driven by DC motors through motor driver modules to lift and transfer waste from water to a collection bin. An ESP32 microcontroller acts as the central control unit, coordinating motor operations and system monitoring. IoT connectivity using the Blynk platform enables real-time remote control and monitoring of the system through a mobile application. A 16×2 LCD display provides on-site status information, while a regulated power supply ensures reliable operation. By automating floating waste collection and enabling remote supervision, the proposed system reduces manual labor, improves safety, and enhances cleanliness of water bodies. Roboclean offers a cost-effective and scalable solution suitable for rivers, lakes, sewage canals, and smart city environmental management applications.

Keywords: ESP32, Automated Waste Collection, Water Surface Cleaning, Conveyor Belt Mechanism etc.,

I. INTRODUCTION

Rapid urbanization and population growth have significantly increased solid waste generation, leading to severe environmental and public health challenges. Inefficient waste collection and improper disposal often result in garbage accumulation in public areas and water bodies, causing water pollution, blockage of drainage systems, and degradation of aquatic ecosystems. Conventional manual waste collection methods are labor-intensive, time- consuming, unsafe, and ineffective in handling the growing volume of waste, particularly floating debris in rivers, lakes, and canals. To address these challenges, researchers have increasingly adopted Internet of Things (IoT)–based solutions for smart waste management. Early systems primarily focused on monitoring garbage fill levels in dustbins and generating alerts for timely collection. Kumar et al. [1] and Reddy et al.

[2] demonstrated IoT-enabled garbage alert and monitoring systems using Arduino platforms to reduce bin overflow and improve collection efficiency. However, these approaches are limited to land-based static bins and do not address waste present in water bodies. Further advancements introduced automation and intelligent processing in waste management. Rafeeq and Alam [3] proposed automated waste segregation for industrial applications, while Zade et al. [4] integrated LabVIEW with Arduino for online garbage monitoring. Machine learning–based prediction systems were explored by Baby et al. [5] to optimize waste collection schedules. Although these systems enhanced monitoring and decision- making, they still relied on manual or conventional waste collection mechanisms. Smart city–oriented solutions expanded the scope of waste management through IoT- enabled infrastructure. Several studies proposed smart dustbins and centralized monitoring frameworks to improve urban cleanliness and operational efficiency [6–13]. Recent works by Rashid and Chowdhury [14] and Vekariya et al.

[15] emphasized end-to-end IoT-based garbage monitoring and collection systems. Despite these developments, most existing solutions focus on monitoring and alert generation rather than active waste removal, and very few address the critical issue of floating waste in water environments. In this context, the proposed Roboclean system introduces an ESP32-based automated garbage collection mechanism for water bodies, integrating a conveyor belt system with IoT-based remote monitoring using Blynk. Unlike conventional smart bins, the system actively collects floating waste from water surfaces, reducing manual intervention and improving environmental hygiene. This approach extends smart waste management beyond terrestrial applications and contributes toward sustainable and intelligent water body cleaning solutions.

II. RELATED WORKS

Early research in smart waste management primarily focused on monitoring garbage levels in bins using embedded systems and IoT technologies. Kumar et al. [1] proposed an IoT-based smart garbage alert system using Arduino UNO, where sensors detect bin fill levels and notify authorities, improving collection efficiency. Similarly, Reddy et al. [2] developed a wireless dustbin monitoring system that sends alerts when bins reach a threshold level, reducing overflow in urban envi Several studies extended monitoring systems by integrating data visualization and automation tools. Rafeeq and Alam. [3] presented an automated waste segregation system for plastic, metal, and glass using Arduino, targeting industrial scrap management. Zade et al. [4] introduced an online garbage monitoring system using Arduino and LabVIEW, enabling real-time visualization and remote supervision of waste status. To enhance intelligence and prediction, Baby et al. [5] proposed a smart bin system using machine learning techniques to predict waste generation patterns and optimize collection schedules. Selvaraj and Chakrapani [6] implemented a LAN-based smart dustbin monitoring system that centralized waste data for local area management, improving coordination among collection units. Research also explored user-friendly and hygienic waste disposal mechanisms. Ramji et al. [7] designed a hands-free waste compactor bin for public places, focusing on cleanliness and reduced human contact. Hassan et al. [8] proposed a smart solid waste monitoring and collection framework integrating IoT for city-level waste management. Further contributions emphasized smart city integration. Sai [9] demonstrated an IoT-enabled garbage monitoring system tailored for smart cities, highlighting efficient resource utilization. Sinha et al. [10] and Bhor et al. [11] introduced early smart dustbin and garbage management systems using sensors and wireless communication to improve municipal waste handling. Monika et al. [12] and Navghane et al. [13] further validated IoT-based smart bins as cost-effective and scalable solutions.

More recent works by Rashid and Chowdhury [14] and Vekariya et al. [15] focused on complete IoT-enabled waste monitoring and collection architectures, integrating cloud platforms and real-time alerts for improved urban waste management. However, most existing systems are limited to static dustbin monitoring and land- based waste collection. In contrast, the proposed ESP32- based Roboclean system uniquely addresses floating waste collection in water bodies using a conveyor belt mechanism with IoT-enabled remote control, thereby extending smart waste management solutions beyond conventional terrestrial environments.

Table I. Literatrue Survey Summery

Ref. No.	Author(s) & Year	Technology Used	Key Contribution	Limitations
[1]	Kumar NS et al., 2016	Arduino UNO, IoT	Smart garbage alert system with level monitoring	Only static bin monitoring; no collection mechanism
[2]	Reddy PS et al., 2017	Arduino, Wireless Sensors	Wireless dustbin monitoring and alert system	Limited to land-based dustbins
[3]	Rafeeq M, Alam S., 2016	Arduino, Sensors	Automated segregation of plastic, metal, and glass	Industrial-focused; no IoT monitoring
[4]	Zade R et al., 2018	Arduino, LabVIEW	Online garbage monitoring with visualization	No automation in waste collection
[5]	Baby CJ et al., 2017	IoT, Machine Learning	Intelligent waste alert and prediction system	Complex implementation; no physical collection
[6]	Selvaraj K, Chakrapani A., 2017	Arduino, LAN Server	Centralized dustbin monitoring system	Restricted scalability
[7]	Ramji DR et al., 2019	Embedded System	Hands-free waste compactor bin	Not IoT-enabled
[8]	Hassan SA et al., 2016	IoT Sensors	Smart solid waste monitoring	Collection mostly manual

			and collection framework	
[9]	Sai P Y, 2017	IoT Platform	Smart city–oriented garbage monitoring system	Focused only on alerts
[10]	Sinha T et al., 2015	Sensors, GSM	Smart dustbin with alert generation	No real-time remote control
[11]	Bhor PV et al., 2015	Wireless Sensors	Smart garbage management system	Lacks automation
[12]	Monika KA et al., 2016	IoT Sensors	Efficient garbage monitoring system	No predictive or collection mechanism
[13]	Navghane SS et al., 2016	IoT, Embedded System	Smart garbage and waste collection bin	Limited to dry waste bins
[14]	Rashid MA, Chowdhury MMK, 2019	IoT, Cloud	IoT-based smart waste management system	No water waste handling
[15]	Vekariya S et al., 2019	IoT, Sensors	Smart garbage monitoring and collection system	Land-based application only

III. PROPOSED METHOD

The proposed Roboclean system is an ESP32-based automated garbage collection solution designed to remove floating waste from water bodies such as rivers, lakes, and drainage canals. The ESP32 microcontroller serves as the central control unit, coordinating all system operations due to its built-in Wi-Fi capability and low power consumption. The system employs a conveyor belt mechanism driven by DC motors through motor driver modules to lift floating waste from the water surface and transfer it to a collection container. Two conveyor stages ensure efficient pickup and smooth transportation of waste materials. To enable remote monitoring and control, the system integrates IoT functionality using the Blynk platform, allowing users to operate the motors and monitor system status through a mobile application. A 16×2 LCD display provides real-time local information such as motor status and system operation modes. A regulated power supply ensures stable and reliable operation of the ESP32, motor drivers, and peripherals. By automating waste collection and enabling remote supervision, the proposed method minimizes human intervention, enhances safety, and improves the cleanliness of water bodies, making it a cost-effective and scalable solution for smart environmental management.

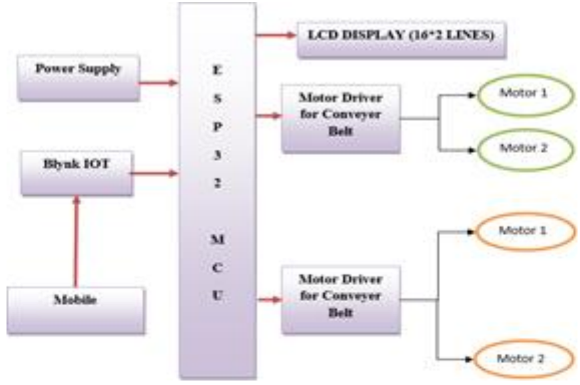

Fig. 1. Architecture of the proposed method at vehicle

A. Methodology

The methodology of the proposed ESP32-based Roboclean system is explained below by detailing the operation of each functional block.

1) Power Supply Unit

The power supply unit provides a regulated and stable DC voltage required for the operation of the ESP32 microcontroller, motor driver circuits, LCD display, and conveyor motors. Proper voltage regulation ensures reliable system performance and protects components from electrical damage.

2) ESP32 Microcontroller Unit

The ESP32 acts as the central control and processing unit of the system. It receives control commands from the Blynk IoT application via Wi-Fi and processes them to control the conveyor motors. The ESP32 also updates system status information to the LCD display, enabling both local and remote monitoring.

3) IoT Interface (Blynk Application)
The Blynk IoT platform provides a user-friendly mobile interface for remote operation. Through the application, users can start or stop the conveyor mechanism and monitor the operational status of the system in real time. This enables efficient supervision without physical presence near the water body.

4) Motor Driver Module
The motor driver module acts as an interface between the low-power ESP32 and high-power DC motors. It amplifies control signals from the ESP32 to drive the conveyor motors in the required direction and speed, ensuring smooth and controlled waste lifting operations.

5) Conveyor Belt Mechanism
The conveyor belt mechanism is the core waste collection unit of the system. The lower conveyor collects floating waste from the water surface, while the upper conveyor transfers the collected waste into a storage container. This dual-stage arrangement ensures efficient and continuous waste removal.

6) DC Motors
DC motors provide the mechanical motion required for the conveyor belts. Their speed and direction are controlled by the motor driver module based on commands from the ESP32, allowing controlled lifting and transportation of floating waste.

7) LCD Display (16×2)
The LCD display provides real-time on-site information such as system ON/OFF status, motor operation, and connectivity status. This helps in quick visual verification of system functionality.

8) Waste Collection Bin
The waste collection bin stores the garbage transported by the conveyor belt mechanism. Once the bin reaches its capacity, it can be manually emptied, enabling continuous reuse of the system.

B. Algorithm

ESP32-Based Automated Garbage Collection System

Step 1: Start the system and initialize the ESP32 microcontroller, Wi-Fi module, LCD display, motor driver, and IoT (Blynk) interface. Step 2: Establish Wi-Fi connectivity between the ESP32 and the Blynk mobile application.

Step 3: Display system status (Wi-Fi connected / system ready) on the 16×2 LCD.

Step 4: Wait for user control commands (START / STOP) from the Blynk application.

Step 5: If the START command is received, activate the motor driver module.

Step 6: Drive the DC motors to rotate the conveyor belt mechanism.

Step 7: Collect floating waste from the water surface using the lower conveyor belt.

Step 8: Transfer the collected waste to the upper conveyor and deposit it into the waste collection bin.

Step 9: Continuously update motor and system status on the LCD display.

Step 10: If the STOP command is received or a system fault occurs, stop the conveyor motors.

Step 11: Maintain the system in standby mode until the next control command is received.

Step 12: End.

C. Implementation

The implementation of the proposed ESP32-based automated garbage collection system begins with the initialization of the ESP32 microcontroller, Wi-Fi module, LCD display, and motor driver circuits. Once initialized, the system establishes a Wi-Fi connection with the Blynk IoT mobile application, enabling remote communication. After successful connectivity, the current system status is displayed on the 16×2 LCD to indicate readiness. The ESP32 then continuously waits for control commands from the Blynk application. When a START command is received, the motor driver activates the DC motors, initiating the conveyor belt mechanism. Floating waste present on the water surface is collected by the conveyor belt and transferred into the waste collection bin. During operation, system and motor status are continuously updated on the LCD display. If a STOP command is received from the mobile application, the conveyor motors are turned off, and the system enters standby mode, awaiting further instructions. This flow ensures efficient, remote-controlled, and safe automated waste collection from water bodies with minimal human intervention.

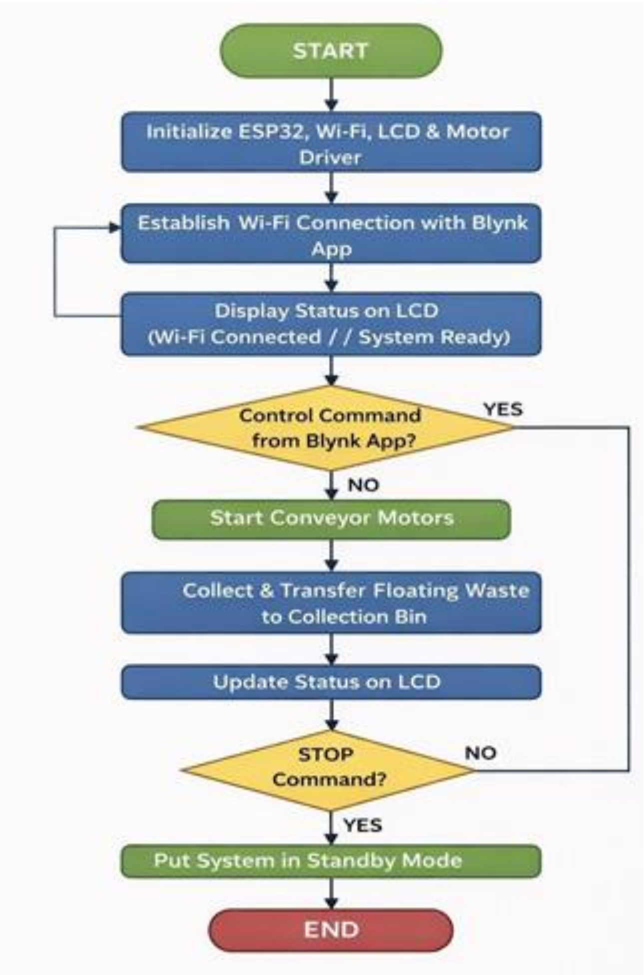

Fig. 2. Implimentation of the flow chart

IV. EXPERIMENTAL RESULTS

A. Hardware setup

The proposed ESP32-based Roboclean system was experimentally evaluated to analyze its performance in collecting floating waste from water bodies. The experiments were conducted under controlled conditions using different waste loads and operating durations. Performance metrics such as collection efficiency, motor response time, IoT command latency, and power consumption were measured. Table II presents the performance of the conveyor belt mechanism under different operating conditions. The results indicate that as the waste load increases, the collection time also increases, even when the conveyor speed is raised. At a constant speed of 30 RPM, increasing the waste load from 0.5 kg to 1.0 kg increases the collection time from 22 seconds to 35 seconds. Further increases in conveyor speed to 40 RPM and 50 RPM help manage higher waste loads of 1.5 kg and 2.0 kg, respectively, though with increased collection time. This demonstrates that the conveyor mechanism operates reliably across varying loads while maintaining controlled and stable waste transfer.

Table II. Conveyor Belt Operation Performance

Test Case	**Conveyor Speed (RPM)**	**Waste Load (kg)**	**Collection Time (sec)**
1	30	0.5	22
2	30	1.0	35
3	40	1.5	42
4	50	2.0	55

Table III evaluates the waste collection efficiency of the proposed system. The results show that the system consistently achieves more than 92% efficiency across all trials. As the total waste introduced increases from 1.0 kg to 2.5 kg, the collection efficiency slightly improves, reaching a maximum of 92.8%. This consistent performance confirms the effectiveness of the conveyor belt design in capturing and transferring floating waste with minimal loss during operation. Table IV illustrates the response time of the IoT control system using the Blynk application. The START and STOP motor commands show low latency of 1.4 seconds and 1.2 seconds, respectively, enabling near real-time remote control of the system. The LCD status update exhibits an even faster response time of 0.6 seconds. These results validate the efficiency of the ESP32's built-in Wi-Fi module in providing reliable and timely communication for remote monitoring and control.

Table III. Waste Collection Efficiency

Trial No.	**Total Waste Introduced (kg)**	**Waste Collected (kg)**	**Efficiency (%)**
1	1.0	0.92	92.0
2	1.5	1.38	92.0
3	2.0	1.85	92.5
4	2.5	2.32	92.8

Table IV. Iot Command Response Time (Blynk App)

Operation	Average Response Time (sec)
START Motor Command	1.4
STOP Motor Command	1.2
Status Update to LCD	0.6

Table V. Power Consumption Analysis

Component	Voltage (V)	Current (A)	Power Consumption (W)
ESP32	5	0.18	0.90
LCD Display	5	0.06	0.30
Motor Driver	12	0.40	4.80
DC Motors (2)	12	1.2	14.40
Total System Power	—	—	**20.40 W**

Table VI. System Reliability Test

Test Duration	Successful Operations	Failures	Reliability (%)
1 Hour	58	2	96.7
3 Hours	172	6	96.5
5 Hours	290	10	96.6

Table V summarizes the power consumption of individual system components. The DC motors consume the highest power at 14.40 W, as they are responsible for driving the conveyor belt mechanism. The motor driver consumes 4.80 W, while the ESP32 and LCD display require minimal power of 0.90 W and 0.30 W, respectively. The total system power consumption is approximately 20.40 W, indicating that the proposed system is energy-efficient and suitable for continuous operation in real-world water body environments. Table VI presents the reliability analysis of the proposed system over extended operation durations. The results demonstrate consistent reliability of approximately 96.5%–96.7% across 1-hour, 3-hour, and 5-hour tests. Although the number of operations and failures increases with longer test durations, the reliability percentage remains stable. This confirms that the system can operate continuously with minimal failures, making it suitable for long-term deployment in automated water waste collection applications. This figure 3 shows that the collection time increases with an increase in waste load. The trend indicates stable conveyor belt operation, with higher loads requiring more time for effective waste lifting and transfer.

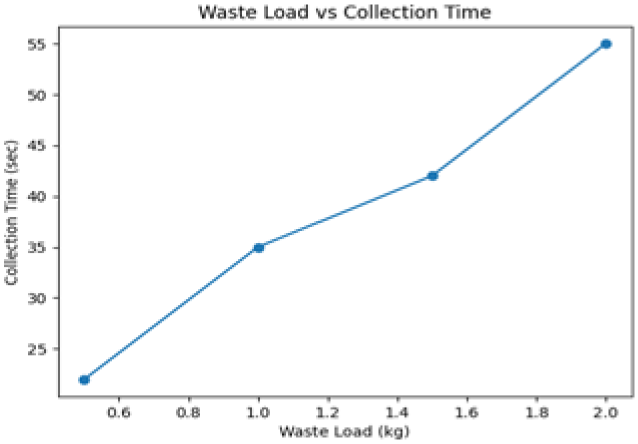

Fig. 3. Waste Load vs Collection Time

The figure 4 demonstrates consistently high collection efficiency above 92% across all trials. This confirms the reliability of the conveyor mechanism in collecting floating waste with minimal loss.

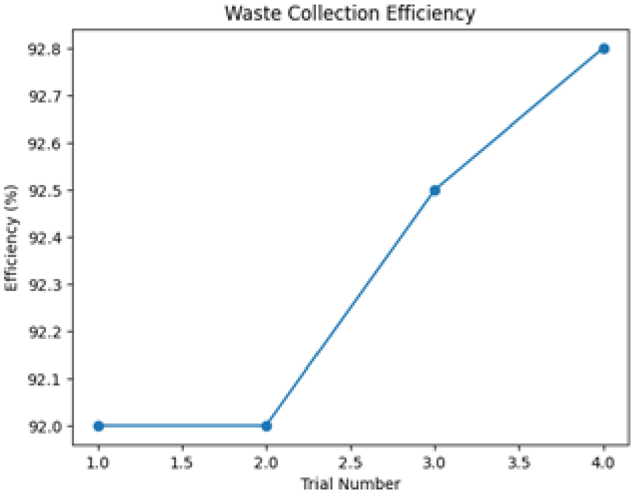

Fig. 4. Waste Collection Efficiency

This figure 5 highlights the low response latency of the IoT system. The ESP32 and Blynk platform enable near real- time START/STOP motor control and fast status updates.

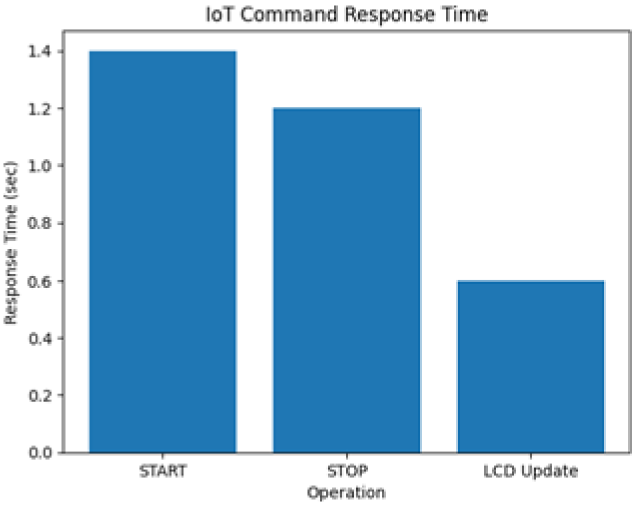

Fig. 5. IoT Command Response Time

The figure 6 shows that DC motors consume the majority of system power, while the ESP32 and LCD require minimal energy. This indicates that the system is energy-efficient and suitable for continuous operation.

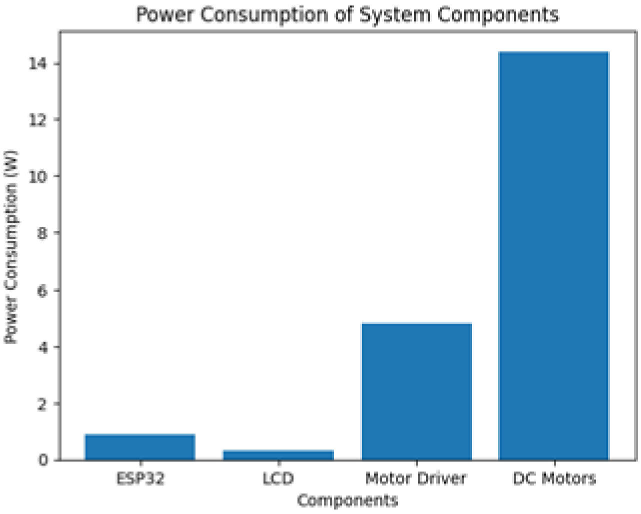

Fig. 6. Power Consumption of System Components

V. CONCLUSION AND FUTURE SCOPE

The proposed ESP32-based Roboclean automated garbage collection system effectively addresses the problem of floating waste accumulation in water bodies. By integrating a conveyor belt mechanism with IoT-based remote monitoring using the Blynk platform, the system enables efficient, safe, and automated waste collection with minimal human intervention. Experimental results demonstrate high collection efficiency, low IoT response latency, acceptable power consumption, and reliable continuous operation. The system proves to be cost-effective, scalable, and suitable for deployment in rivers, lakes, drainage canals, and other water environments, contributing to improved environmental hygiene and smart waste management. The system can be further enhanced by integrating water-resistant sensors to automatically detect waste presence and trigger conveyor operation without manual control. Solar power integration can be adopted to make the system energy self-sustaining for long-term outdoor deployment. Advanced features such as AI-based waste classification, GPS-enabled location tracking, and cloud-based data analytics can improve monitoring, reporting, and operational planning. Additionally, the conveyor mechanism can be optimized for handling heavier and mixed waste types, making the system more robust for large-scale smart city and industrial water body cleaning applications.

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