

CleanBot: The Smart Waste Collector

Sushanka P G, Shravya, Tejaswini D, Sudha H P, Dr. Bhagyashri R. Hanji

Student, Student, Student, Student, Professor
Department of Information Science and Engineering,
Global Academy Of Technology, Bangalore, India

sushankapg1ga22is169@gmail.com, shravyashetty415@gmail.com, tejaswinigowdateju1438@gmail.com,
sudhahpsudha@gmail.com, bhagyashri@gat.ac.in

Abstract— Waste accumulation in water bodies has become a serious environmental concern, leading to pollution and health hazards. Manual waste collection is often inefficient, time-consuming, and labor-intensive. To address this issue, trash collecting robots offer an effective and sustainable solution. The process involves visually identifying the floating waste through manual observation and collecting them through a remote-controlled robot. These robots can function in water environments, efficiently collecting and transporting waste to designated areas. They minimize human effort, operate with precision, and contribute to cleaner surroundings. In aquatic regions, they help remove floating waste, improving water quality and protecting aquatic life. By ensuring timely and organized waste management, these robots promote sustainability, reduce human intervention, and represent a significant step toward achieving cleaner and smarter cities.

Index Terms— Waste management, Trash collecting robot, Water pollution, Remote control, Sustainability, Aquatic environment

I. INTRODUCTION

Waste management has become a pressing environmental, social, and technological challenge in rapidly developing urban regions. According to the Central Pollution Control Board (CPCB), India generates nearly 1.6 lakh tons of solid waste per day, and a significant portion of it remains uncollected or improperly segregated. Metropolitan cities such as Bengaluru and Mumbai are among the top contributors, producing around 5,500 and 7,000 tons of waste daily, respectively. Improper waste handling practices lead to overflowing dustbins, foul odors, mosquito breeding, and clogging of drainage systems, causing health and environmental hazards. These growing issues highlight the urgent need for automated and efficient waste collection systems that can assist in maintaining urban hygiene and sustainability.

In addition to solid waste on land, water pollution in lakes, rivers, and other water bodies has become a significant concern. Floating waste such as plastics, bottles, leaves, and organic debris accumulates due to improper disposal and urban runoff. Manual cleaning of these water bodies is time-consuming, labor-intensive, and hazardous. Workers involved in such cleaning operations are exposed to toxic materials, unpredictable weather, and unsanitary conditions, increasing their health risks. For example, Bellandur and Varthur lakes in Bengaluru and the Mithi River in Mumbai have become symbols of water pollution caused by urban waste discharge and floating debris. These real-life scenarios show the need for manual robotic systems that can assist or replace manual cleaning methods, reducing human risk while increasing efficiency.

In India, water bodies play a vital role in maintaining ecological balance and ensuring water security. However, the accumulation of trash, industrial waste, and sewage discharge severely impacts aquatic ecosystems, biodiversity, and public health. During the monsoon season, the inflow of urban waste through drainage systems adds an additional burden on civic bodies. Despite ongoing cleanup efforts, manual collection of waste remains inefficient due to limited resources and accessibility challenges. The deployment of robotic systems and unmanned surface vehicles (USVs) offers a modern approach to address this issue by debris collection in confined water bodies such as temple ponds, swimming pools, and small lakes. These systems can be remotely operated and adapted to various conditions, ensuring better coverage and consistent cleaning performance.

Lifestyle changes and the increased use of single-use plastics have further worsened waste management challenges. Most disposable materials, including plastic bottles, food wrappers, and packaging materials, are often discarded improperly into open areas or water bodies. Such practices directly threaten hygiene and aquatic health, leading to long-term pollution and damage to water quality. While manual methods of waste removal are still common, they are inefficient for large-scale or continuous cleaning operations. Therefore, there is a growing shift toward technological innovations that combine robotics, automation, and IoT-based systems to support efficient waste collection and disposal.

The current scenario of waste collection still largely relies on human labor, where workers use mechanical tools to collect and dispose of trash. However, this approach has limitations in terms of speed, safety, and scalability. In some modern systems, mobile robots and semi-autonomous cleaning boats are being developed to assist workers in collecting floating waste and cleaning confined surfaces. These robots can perform simple functions like moving, collecting, and unloading waste, often controlled through remote or Bluetooth-based systems. By integrating Arduino microcontrollers, Finite State Machines (FSM), and Bluetooth modules, such robots can be designed to perform predefined actions based on user input, ensuring efficient operation while maintaining low cost and simplicity.

The Finite State Machine (FSM) approach helps structure the robot's operation into distinct states such as Idle, Move, Collect, Dispose, and Return allowing smooth transitions between tasks based on Bluetooth commands. FSMs make the system predictable, reliable, and easier to control in real time. Using Arduino IDE, the entire system can be programmed for responsive control through a Bluetooth-enabled device, allowing users to manually operate the robot for tasks like moving forward, backward, turning,

collecting, or stopping. This method not only simplifies the robot's design but also enhances its usability in practical waste management scenarios.

The increasing success of such robotic systems demonstrates the potential of automation, embedded systems, and IoT technologies in addressing modern waste management problems. They align with national initiatives like the Swachh Bharat Mission and Smart City Projects, promoting innovation in sustainable urban development. By replacing manual labor with human-controlled robotic systems, cities can move toward cleaner, safer, and smarter waste collection practices. This literature survey focuses on exploring previous research, existing technologies, and the evolution of robotic waste collection systems, with particular emphasis on Bluetooth- controlled FSM-based trash collecting robots built using Arduino microcontrollers.

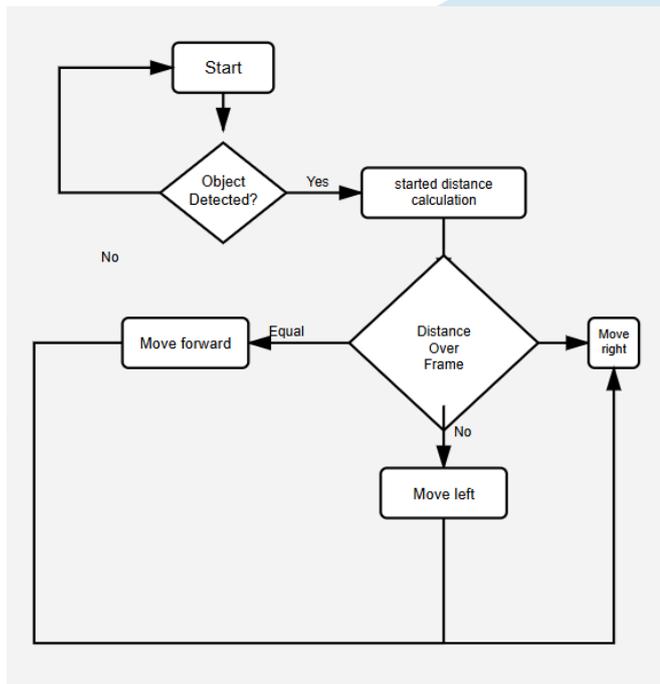


Fig 1 – Block diagram of Smart Waste Collector

With advancements in automation and wireless control, trash-collecting robots provide an efficient and safe alternative to manual waste handling. The integration of Arduino, FSM, and Bluetooth ensures precise control and real-time operation. This study focuses on developing a cost-effective and sustainable robotic system to support smart waste management initiatives.

II. PROPOSED METHODOLOGY

The proposed methodology focuses on developing an autonomous trash collection robot that utilizes a finite state machine (FSM) algorithm integrated with IOT technology for efficient and intelligent waste collection from water bodies. The system is designed to detect, classify, and collect floating trash while communicating real-time operational data to a cloud-based monitoring system. The methodology can be divided into several key stages:

A. System Initialization

At the beginning, the communication modules and actuators are initialized. The Arduino UNO serves as the main controller, interfacing with the Bluetooth module (HC-05), and motor drivers (L298N). The system ensures all hardware components such as DC motors, servos, and power modules are functional before entering the operational states.

B. FSM-Based Decision Control

The Finite State Machine (FSM) algorithm governs the robot's behavior through a set of predefined states. The system transitions between these states based on real-time sensor inputs and environmental conditions. The key operational states are:

- Idle State – The robot awaits user command or activation signal.
- Search State – The robot moves across the water surface for trash detected through manual observation.
- Collect State – The robotic collection mechanism is activated to pick up trash and store it in the onboard bin.
- Avoid Obstacle State – The robot changes direction or speed to avoid collisions with floating obstacles or boundaries.
- Return/Disposal State – When the trash bin is full or the task is completed, the robot is navigated to a disposal or docking station.

C. IOT Integration

After each operation or state transition, The robot operates manually, where:

- The trash location is identified through manual observation.
- The robot is controlled remotely to move to the detected trash area.
- The robot collects the trash and stores it in the container.

The ESP32 or HC-05 module manages this communication through Bluetooth protocols.

D. Actuation and Navigation Control

The Arduino UNO processes FSM outputs and sends corresponding control signals to the L298N Motor Driver, which regulates the speed and direction of the DC geared motors. The navigation system ensures smooth movement in forward, backward, left, or right directions. Servo motors are controlled to activate the trash collection arm, allowing precise collection and storage of waste.

E. Real-Time Monitoring and Feedback

The robot continuously sends operational feedback to the user interface. The Arduino Bluetooth Controller App (developed using MIT App Inventor) allows manual override, monitoring of status updates, and emergency stop controls. This ensures both autonomous and semi- autonomous modes of operation.

F. System Termination and Maintenance

Once the collection cycle is completed, the robot transitions to an Idle or Docking State, where it can recharge its battery or offload collected trash. The cloud system logs all operational data for performance analysis and system improvement.

III. NOVELTY AND CONTRIBUTION

A. Integration of FSM and IoT

The project introduces a unique combination of Finite State Machine (FSM) control and IoT-based monitoring, enabling adaptive, autonomous decision-making and real-time communication for efficient trash collection.

B. Adaptive State-Based Control:

Using FSM, the robot intelligently transitions between operational states such as Collect, Avoid Obstacle, and Dispose, ensuring smooth and context-aware navigation in dynamic water environments.

C. Cost-Effective and Scalable Design:

The system uses low-cost components like Arduino UNO, HC-05 Bluetooth, and L298N motor driver, making it affordable, energy-efficient, and easily scalable for larger or different cleaning applications.

D. Environmental and Societal Impact:

The robot automates water surface cleaning, reducing human exposure to polluted environments and promoting sustainable waste management, contributing to cleaner ecosystems and smart city initiatives.

E. Technical Advancement:

The project demonstrates how FSM-driven robotics integrated with IoT can achieve real-time adaptability, reliability, and intelligence in autonomous environmental service systems.

IV. LITERATURE REVIEW

In paper (1) the authors discuss an autonomous garbage-collecting robotic system that operates on small water bodies. The system is designed to detect floating waste and collect it using a mechanized platform. Sensors and a camera module guide the robot for navigation and obstacle avoidance. The robot uses an optimized water-surface traversal algorithm to maintain stable movement even in mildly disturbed waters. A conveyor mechanism helps the system lift trash efficiently. The authors highlight the low-cost design and its ability to continuously monitor water bodies. The robot is lightweight and energy-efficient, ensuring long operational runtime. Experiments show successful garbage collection in ponds and lakes. Data transmission enables real-time status monitoring. The authors propose enhancements such as using AI for improved garbage recognition. This work contributes toward reducing manual labor in hazardous cleaning operations.

Paper (2) authors concentrate on using autonomous service robots for urban waste management with multi-agent planning. A fleet of robots cooperates to cover large municipal areas efficiently. The core contribution is a multi-agent route-planning framework that reduces distance and overlap between robots. Communication protocols allow robots to negotiate tasks and coordinate operations. Motion planning ensures safe navigation in crowded urban environments. The system reduces cost, fuel, and time in municipal waste collection. Simulations and field trials demonstrate scalability for smart-city deployment. The paper also highlights robustness in dynamic traffic conditions. The scheduling algorithm adapts to the availability of robots and changing waste density. The authors recommend future integration with smart-bin IoT infrastructure. Overall, the system represents a shift toward automated urban sanitation.

In paper (3), the authors propose a vision-based outdoor garbage collection robot. A deep-learning-powered camera system allows detection and differentiation of waste types on streets. The robot navigates autonomously and uses robotic arms for picking trash. Real-time image processing helps it classify garbage on rough terrains. Lane-detection techniques keep the robot aligned with sidewalks. The mobility platform is optimized for outdoor uneven surfaces. The authors investigate robustness under varying lighting and weather conditions. Experiments show high garbage-recognition accuracy. The system reduces manual labor and increases collection efficiency. The authors suggest future work on integrating recycling-based sorting.

Paper (4) presents a river-surface trash-collecting robot powered by solar energy. The energy-harvesting approach allows long-term autonomous functioning. Solar panels supply power to navigation, trash-collection, and communication units. The robot uses ultrasonic sensors for obstacle detection. A belt-driven mechanism collects floating trash into a storage basket. The design emphasizes sustainability by removing dependency on fuel or charging. Field tests on rivers and canals illustrate effective trash removal. The authors report high autonomy and minimal maintenance. Monitoring software enables periodic status updates. The system provides an environment-friendly solution for cleaning large water bodies.

Paper (5) provides a review of various trash-collecting and cleaning robots. The authors categorize systems based on land, water, and hybrid platforms. Mechanisms such as mechanical arms, conveyor belts, and net-based collectors are discussed. Key challenges highlighted include battery life, terrain adaptability, and trash detection accuracy. The authors compare autonomous, semi-autonomous, and manual-assisted systems. The review identifies emerging trends such as AI-vision, IoT, and renewable power integration. Cost and scalability limitations are also addressed. Application domains range from household cleaning to ocean trash removal. Future scope includes more modular and self-diagnosing robots. The study presents a holistic understanding of the present state of robotic waste management.

Paper (6) focuses on an IoT-controlled trash-collecting robot operated via an Android application. The system enables remote human control through Bluetooth or Wi-Fi. A mobile interface gives direction and task commands. Ultrasonic sensors ensure collision avoidance during motion. The mechanism includes a scoop-style collector to gather floating trash. The IoT approach reduces physical human effort in hazardous environments. Experimental analysis shows reliable connectivity and responsiveness from the smartphone app. The authors demonstrate compatibility with multiple processors and microcontroller modules. Real-time alerts ensure safe operation. The paper concludes with potential improvements like complete autonomy and solar charging.

Paper (7) demonstrates an automated waste control management system using Arduino. Smart bins use sensors to detect fill levels and alert authorities. Wireless communication enables data transfer to a central dashboard. The system optimizes timings of waste collection trucks. An alarm system prevents overflow and hygiene issues. The IoT infrastructure contributes to cleaner urban spaces. The authors analyze hardware cost and conclude that it is economically scalable. Integrating Arduino ensures low power consumption. Prototype testing validates performance in varied environmental conditions. The system can be extended by adding predictive analytics.

Paper (8) presents a robotic action system specifically oriented toward plastic collection. The authors highlight the environmental dangers of plastic trash in oceans and rivers. The robot uses AI-assisted perception to detect plastic materials. A gripping arm separates plastic from non-plastic waste. Real-time decision-making improves collection accuracy. The mobility platform supports long-range patrolling of water bodies. The study focuses on increasing precision in plastic identification. Experiments confirm consistent operation over long durations. The system has strong potential in marine ecosystem conservation.

Paper (9) describes an autonomous boat that collects and classifies floating trash. Object-recognition algorithms categorize trash types during the collection process. The boat uses GPS and sensors for autonomous navigation. The storage unit has sections for sorted waste categories. Classification reduces later recycling effort. Trials in lakes and reservoirs show high accuracy. The robot adapts to subtle water currents. Energy optimization improves operational duration. The authors propose future real-time mapping of waste density across water bodies.

Paper (10) develops a vision-based outdoor garbage collection robot similar to paper (3) but focuses on dataset generalization. Deep convolutional networks detect diverse garbage types found in public spaces. The navigation model uses path estimation and obstacle avoidance. Trash-pickup motions improve efficiency in narrow locations. Field tests show robustness against rain and shadows. The authors compare different CNN architectures and select the most lightweight and efficient one. The study highlights the need for scalable datasets for garbage recognition.

Paper (11) proposes an unmanned floating waste-collecting robot. The mechanism includes rotating paddles that push trash into a storage container. A low-cost hull design supports stability even in choppy waters. Remote control and autonomous modes are both supported. The system is modular for easier maintenance and upgrades. The authors evaluate throughput based on trash volume collected per hour. A cloud-monitoring module could be added for deployment in smart-cities. The robot reduces dependency on man power for water cleaning.

Paper (12) introduces a solid-waste cleaning robot for ponds. The design uses a filtering mesh to remove debris floating near the water surface. A motorized raft enhances maneuverability. The robot is durable and suitable for indigenous water bodies. Testing results reflect successful operation in community ponds. The system is cost-effective and easy to maintain. User recommendations include solar-power integration and smart sensing for autonomy. The focus is on practical deployment rather than high-end automation.

Paper (13) concentrates on predicting trash-bin levels in urban areas using deep LSTM networks. The model processes historical garbage-accumulation data. Predictive analytics help schedule waste-collection trucks before bins overflow. The use of spatiotemporal patterns enhances accuracy. The system improves resource allocation and fuel efficiency. The authors validate the model on municipal data. Deployment reduces manual monitoring by authorities. Recommendations include linking prediction to autonomous waste-collection planning.

Paper (14) proposes an IoT-based precision waste-collection platform for smart cities. Smart sensors measure garbage levels in bins and transmit data to a cloud dashboard. Routing algorithms determine optimal truck movement to reduce travel time. The system prevents overflowing in commercial zones. Citizens can view bin status through a smart mobile interface. The architecture shows promise in real-world deployments. Energy consumption of nodes is minimized to extend sensor lifetime. The authors conclude that IoT-based waste monitoring is key for sustainable cities.

Paper (15) focuses on AI-based waste-collection prediction and optimization. Machine-learning models forecast waste generation patterns. Optimization algorithms allocate vehicles and route schedules. The framework reduces operational cost and emissions. Analytics dashboards support decision-making for authorities. Experiments show high prediction accuracy. The model adapts to seasonal events and population density patterns. The authors suggest integrating the model with smart-bin systems for automation.

Paper (16) presents an integrated future model combining IoT with block chain for smart-city waste management. IoT sensors collect bin-filling data and environmental metrics. Block chain ensures secure and tamper-proof data transactions. Decentralization prevents manipulation and increases trust between authorities and service providers. Smart contracts automate payments and service transparency. The paper highlights cyber-security as essential for smart-city deployments. The proposed architecture enhances accountability and efficiency. The authors foresee block chain as a core element of next-generation waste management frameworks.

V. RESULTS

The developed trash collection robot successfully demonstrated its ability to navigate water surfaces and collect floating waste using Bluetooth-based manual control. The robot responded accurately to directional commands forward, reverse, left, and right—transmitted through the Arduino Bluetooth Controller App, ensuring smooth maneuverability. The DC motor system, driven by the L298N motor driver, provided stable propulsion, enabling the robot to float and move effectively in confined water bodies such as small lakes, ponds, and pools.

During testing, the robot's collection mechanism operated reliably by guiding floating debris into the onboard collection bin. The system maintained consistent performance in detecting obstacles and avoiding collisions, ensuring uninterrupted navigation. The use of FSM-based state transitions (Idle, Search, Collect, Avoid, Return) improved task execution and reduced operational delays. Visual inspection confirmed that the robot could collect common floating debris such as leaves, plastic wrappers, and small plastic bottles. Communication between the Bluetooth module (HC-05), Arduino UNO, and the motor system remained stable throughout the operation, with minimal signal loss within the testing range.

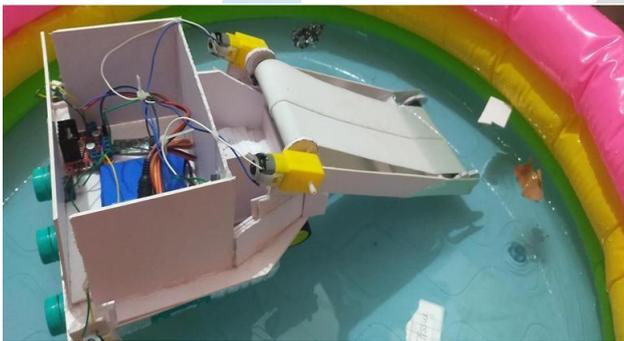


Fig 2: Representation of Prototype Model

Overall, the prototype effectively validated the feasibility of a low-cost, Arduino-based trash collection robot for water surface cleaning. The results indicate that the system can support small-scale environmental cleaning tasks, reduce manual labor, and offer a foundation for future enhancements such as full autonomy, IoT monitoring, and improved debris detection.

VI. CONCLUSION

The Trash Collection Robot, controlled through a mobile app, offers an innovative solution for cleaning water bodies. The robot integrates an Arduino Uno, DC motors, a Bluetooth module, and sensors, enabling it to navigate autonomously and collect waste. The Bluetooth module allows the user to control the robot remotely via the mobile app, making it easy to operate and monitor its movements. The mobile app provides an intuitive interface for controlling the robot's actions, such as moving forward, backward, and turning. It also allows users to receive real-time feedback on the robot's status, ensuring smooth operation. The robot uses sensors to detect obstacles and avoid collisions, ensuring efficient navigation in the water. This project demonstrates the potential of robotics and IoT in environmental conservation. By automating the process of trash collection, it offers a more sustainable and cost-effective approach to maintaining cleaner water bodies, contributing to a healthier ecosystem. The mobile app serves as the interface for controlling the robot, offering a simple and intuitive way to manage its operations. It allows users to send commands for movement, such as forward, backward, and turning, and provides feedback on the robot's position and actions. This makes the system highly user-friendly, even for those with minimal technical experience.

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