An Intelligent System to Manage Garbage in Cities

Dr Parameswaran T [1], Sheshadri M O [2], Bindushree N [3], Greeshma N [4], Shraddha N [5]

[1] *Associate Professor, Dept. of Computer Science & Engineering, CMR University, Bengaluru.*
[2345] *UG Student, Dept. of Computer and Communication Engineering, CMR University, Bengaluru.*

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Abstract - The increasing population and rapid urbanization have led to challenges in the waste management systems, particularly in densely populated areas. Traditional waste collection systems are facing issues such as inefficiency, overfilled bins, and delays in waste collection, which can result to environmental hazards. To state these issues, the Smart Waste Dustbin System was developed using Internet of Things (IoT) technology. This system integrates various sensors (IR, rain, and ultrasonic) with an ESP32 microcontroller to create an intelligent waste management solution capable of sorting waste, monitoring bin fullness, and providing real-time location tracking.
The sensor is often used to measure the level of waste in the bin, providing data on whether the bin is empty, half-filled, or full. The servo motor is activated to sort waste into the appropriate compartment based on the type detected. The system also integrates GPS technology to track the location of the bin in real-time, which is useful for waste collection services and tracking waste disposal activities

Key Words: Smart Waste Dustbin, Waste detector, IR Sensor, ultrasonic, ESP32 microcontroller, Internet of Things, GPS location

INTRODUCTION

With the rapid growth of urban populations and the increasing rate of waste generation, efficient waste management work has become a significant challenge in cities worldwide. Traditional waste management methods, such as manual collection and sorting, are often inefficient, time-consuming, and prone to human error. as a result, waste bins frequently overflow causing sanitation issues, environmental pollution, and higher costs for municipalities

In this context, the Smart Waste Dustbin System presents an innovative solution by utilizing Internet of Things (IoT) technologies to automate waste detection, sorting, and monitoring. By incorporating sensors, a microcontroller, and wireless communication, this system enhances the efficiency of waste management in smart cities.

The system is designed to achieve the following goals:

Automated Waste Sorting: Using IR sensors and rain sensors, the system identifies and classifies the waste as either dry (non-biodegradable) or wet (biodegradable). The waste is automatically sorted into appropriate compartments via a servomotor, thus simplifying the recycling process.

Bin Fullness Monitoring: The ultrasonic sensor continuously measures the distance to the waste level inside the bin, determining whether the bin is empty, half-filled, or full. This data helps optimize the waste collection process by preventing overflows and reducing unnecessary waste collection trips

Real-tine Status Updates: Through integration with the Blynk app, users can monitor the status of the waste bin. They can receive real-time updates regarding the type of waste, bin fullness, and even the location of the bin using GPS technology.

Location Tracking: The GPS module provides precise location coordinates of the bin, making it easier for waste collection teams to locate bins that require attention. This feature is particularly useful for urban areas with numerous waste bins spread across large regions.

The core components of the system include the ESP32 microcontroller, which serves as the brain of the system, IR and rain sensors for detecting waste type, ultrasonic sensors for monitoring bin fullness, servo motors for sorting waste, and the GPS module for location tracking. These components work in conjunction to ensure the system operates seamlessly, sending real-time data to the Blynk app and triggering alerts when necessary.

This system provides an efficient and automated approach to managing urban waste, contributing to cleaner cities and more sustainable waste practices. By implementing IoT solutions, it reduces the dependency on manual and optimizes the waste

collection process, making it both cost-effective and environmentally friendly. Furthermore, the real-time data and monitoring capabilities allow for better decision-making and planning in waste management operations.

In summary, the Smart Waste Dustbin System is designed to modernize waste management by incorporating automation, real-time monitoring, and location tracking. It exemplifies the potential of IoT technology to solve pressing urban issues and plays a vital and important role in the development of smart cities where technology is integrated into everyday life for greater convenience, sustainability, and efficiency.

1. LITERATURE SURVEY

The subject of utilizing Internet of Things (IoT) in waste management has gained significant attention in recent and forthcoming years as urbanization has rapidly increased, creating challenges in waste disposal and management. Smart waste management and disposal systems aim to automate waste collection, sorting, and monitoring, improving the overall efficiency of the process. Numerous studies and projects have explored the integration of IoT, sensors, and cloud platforms in waste management. Below is an overview of the most relevant literature in this area.

1.1. IoT-Based Waste Management Systems

IoT (Internet of Things) is transforming the way we will manage waste by connecting smart devices like sensors to the Wi fi internet. This helps us collect and sort waste more efficiently. For example, V. M. R. R. S. Manogar and his team (2016) came up with a smart system that uses ultrasonic sensors for checking how full trash bins are, temperature sensors to spot potentially hazardous materials, and RFID tags to track bins in real-time. All the data from these devices is sent to a central server, where it's analyzed to find the best roots for waste collection, saving time and resources.

Similarly, T. Shankar and S. R. K. Jadhav (2020) developed the system that uses ultrasonic sensors to monitor bin fullness and send alerts when the bins are full. They even added solar-powered bins to make the system more eco-friendly and energy-efficient, helping to lower electricity costs. These systems aim to reduce unnecessary waste collection trips, optimize collection routes, and cut down on the costs associated with manual waste collection.

1.2. Waste Sorting Technology

Sorting waste properly is key to reducing landfill waste and promoting recycling. In one study, K. P. Ramachandran and his team (2018) created an automatic waste sorting system using infrared sensors, color sensors, and servo motors. The system sorts materials into dry and wet waste categories, making it easier to recycle. Their research highlights how crucial accurate sorting is for improving recycling efficiency.

S. S. Hossain and his colleagues (2021) took it a step further by combining infrared sensors with moisture sensors to differentiate between wet and dry waste. They also added artificial intelligence (AI) to help the system learn and improve its sorting capabilities. This combination of IoT and AI can help make waste sorting faster and more accurate, reducing the effort required for manual sorting.

Automated sorting systems could save us a lot of time and energy, making recycling easier and more efficient.

1.3. Ultrasonic Sensors in Waste Management

Ultrasonic sensors are great for monitoring how full trash bins are, helping optimize waste collection. In 2017, S. R. Sahasrabuddhe and his team developed a system that used ultrasonic sensors to measure waste levels. The data was sent to a cloud server where the collection schedule was adjusted based on real-time information. This means waste management companies should avoid wasting resources by collecting waste from bins that aren't full.

M. A. H. Tarek (2018) built a similar system, where ultrasonic sensors detected the waste level in bins and transmitted that data to a cloud platform. This not only helped with waste monitoring but also made it easier to optimize the routes of waste collecting vehicles, which cuts unnecessary trips and lowering the impact of waste collection.

1.4 GPS Integration for Waste Tracking

GPS technology is also playing a big role in modern waste management. By tracking the exact location of bins, waste management companies can plan and optimize collection routes more effectively. A study by A. S. Shukla and his team (2016) demonstrated how GPS coordinates could be used to identify the best roots for waste collection trucks, helping save time and fuel.

H. R. M. Poona (2016) took this even further by integrating GPS with IoT systems. This allowed for precise, real-time tracking of bins, improving the logistics of waste collection. In large cities where bins are spread far apart, this level of precision helps ensure that collections happen in time and in the most efficient way possible.

1.5. Cloud Integration and Remote Monitoring

Cloud platforms like Blynk, Thing Speak, and AWS IoT are becoming the backbone of many IoT-based waste management systems. They allow waste management teams to store, process, and analyze data from all the sensors in a central place. For example, M. S. Khan and his team (2020) developed a cloud-based system using Blynk to track the fullness of waste bins. The system sent alerts to waste management teams when bins were full, helping them collect waste promptly.

Cloud integration makes it easy to monitor waste systems in real-time, even from a distance. Plus, it supports scalability, meaning the system will grow as the quantity of bins and sensors increases, making it adaptable to both small and large-scale waste management needs.

1.6. Challenges and Future Directions

While IoT-based waste management systems have many benefits, there are still challenges to overcome. Issues like sensor accuracy, power consumption, and the cost of implementing these systems on a larger scale in urban areas can make it intact to fully realize their potential. Plus, systems that rely on continuous internet connectivity might struggle in areas with weak network signals.

In the future, researchers could focus on developing low-power sensors and more energy-efficient systems. AI and machine learning could also play a bigger role, helping to predict and optimize waste collection based on patterns and trends. By addressing these challenges, we can make waste management even more sustainable and reduce its environmental impact.

2. Applications

The Smart Waste Dustbin system, integrating sensors, servos, ultrasonic technology, and IoT features, has various potential applications in multiple domains. The following are some of the prominent applications of the system:

2.1. Smart Cities and Urban management

Waste Management Optimization: The Smart Waste Dustbin system can play a role in the smart city initiative by automating waste segregating and monitoring bin fullness levels. It helps authorities optimize waste collection root and schedules based on the real time status of waste smart bins, minimizing manual intervention and improving operational efficiency

Reducing Overflows: By notifying the authorities when the bins are full through the Blynk app, the system prevents waste bin overflows, which are common in crowded urban areas. This results in cleaner public spaces and a reduction in waste-related health hazards.

Efficient Resource Allocation: City waste management departments can use the real-time data provided by the system to allocate resources (trucks, workers) more effectively. This can reduce fuel consumption, lower costs, and ensure waste is collected in a timely manner

2.2. Environmental Protection

Waste Segregation and Recycling: The Smart Waste Dustbin system helps in sorting dry and wet waste at the source itself. This leads to improved waste segregation, which is vital for recycling processes. With accurate sorting, recyclable materials such as paper, plastic, and metal can be easily separated from organic waste, promoting sustainability and reducing, decreasing the environmental impact of landfills

Promoting Eco-Friendly Practices: By encouraging users to dispose of waste in the right category (wet or dry), the system can help raising awareness about environmental responsibility. The real time data got by the system will also be used to generate reports and insights, promoting better waste management practices.

2.3. Residential and Commercial Use

Home and Office Waste Management: For households and offices, the system can be deployed as a smart waste disposal solution. The automatic sorting of wet and dry waste ensures that the waste is organized and ready for recycling or composting, thus promoting eco- friendly living.

Alert system for Full Bins: The built-in buzzer and Blynk app alerts inform residents or facility managers when the bin is full and needs emptying, eliminating the inconvenience of overfilled bins and maintaining cleanliness.

Customized Waste Sorting: With adjustable servo positions and sensor thresholds, users can customize the sorting mechanism for different types of waste, enabling more personalized and efficient waste disposal practices.

2.4. Commercial Establishments and Public Spaces

Public Parks, Malls, and Schools: In public spaces like parks, malls, or educational institutions, this system can be used to ensure proper waste management, keep track of bin status remotely, and maintain cleaner, more hygienic environments. It also helps in automating waste collection, allowing facilities to reduce costs and manage waste efficiently.

Hotels and Restaurants: These businesses generate a significant amount of waste daily. The Smart Waste Dustbin system can be implemented in kitchens and dining areas to automate waste categorization and make sure that waste is sorted before being collected. This can help businesses with regulations on waste segregation and contribute to sustainability goals

2.5. Industrial and Manufacturing Facilities

Waste Management in Factories: Industrial facilities produce various types of waste, including dry waste (like plastic, metal, and paper) and wet waste (like organic matter and liquids). The Smart Waste Dustbin system can automate waste sorting and monitor bin fullness, ensuring that the facility adheres to environmental standards and reduces waste management costs.

Improved Recycling Programs: The accurate detection and segregation of waste at the source can boost the facility's recycling initiatives, improving sustainability and helping businesses meet their social responsibility (CSR) goals

2.6. Environmental Monitoring and Data Analytics

Waste Generation Analysis: The data generated by the Smart Waste Dustbin system can be used to analyze the volume of waste produced in specific areas. This data can help environmental researchers, municipalities, or businesses make informed and efficient decisions about waste reduction, recycling programs, and the overall environmental footprint.

IoT-Based Smart Waste Systems: The system serves as part of a larger IoT based waste management network, where waste bins are interconnected with central servers that monitor real time data from various locations. This type of connected system enables municipalities to manage waste in a more efficient, data-driven way.

2.7. Integration with Smart Technologies

Smart Home Automation: The Smart Waste Dustbin system can be integrated with other smart home devices, such as lights, smart thermostats, and home assistants like Google Hone or Amazon Alexa, for a seamless and automated home management experience. For example, a voice command could be used to check the status of the waste bin or to trigger an alert when the bin is full.

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Fleet Management: The system could also be integrated with waste collection fleet management systems. The GPS tracking feature in the dustbin will allow authorities or waste collection agencies to efficiently route garbage trucks based on the real-time status of waste bins.

2.8. Future Innovations

Automated Waste Collection Robots: In the future, this system could be integrated with robotic waste collection units that move around and autonomously collect trash from different locations. The system's data on bin fullness and waste type can guide these robots to the nearest full bin, improving efficiency.

Smart Waste Processing: With advancements in technology, smart dustbins could also be linked to automated waste processing systems for recycling and composting. The system could automatically sort, process, and even manage the waste disposal process end-to-end, making it more effective and environmentally friendly.

2.9. Emergency Management

Disaster Relief Operations: In the aftermath of natural disasters, the Smart Waste Dustbin system can be deployed in disaster relief zones to efficiently handle the waste generated from relief operations and help manage sanitary conditions in disaster-stricken areas.

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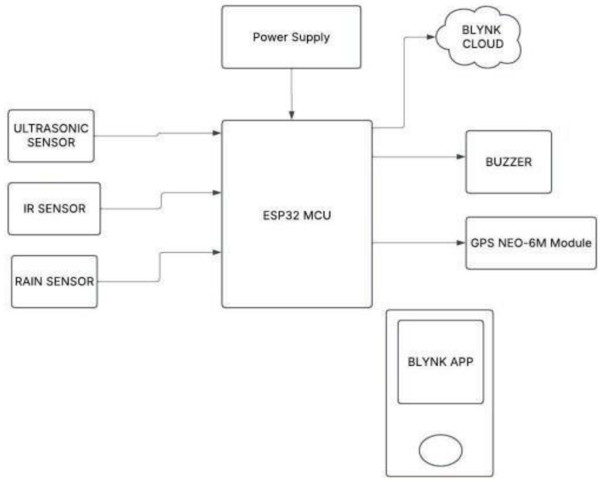

Fig 1: Block Diagram

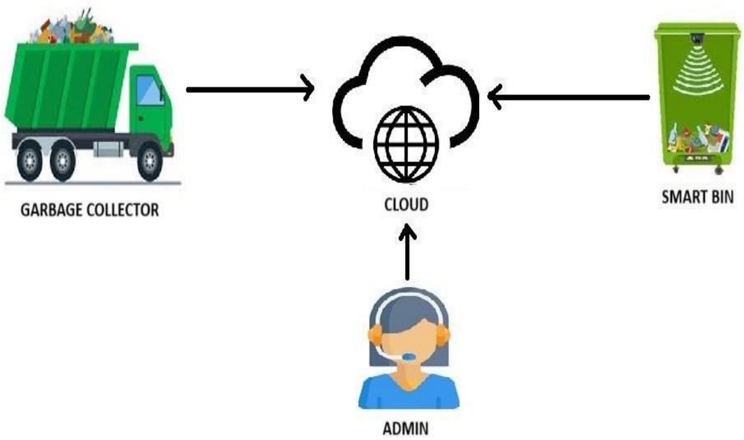

Fig 2: Architecture

3. Block Diagram Components

A block diagram represents the major components of the Smart Waste Dustbin system and shows how these components interact with one another. It helps in visualizing the system's structure and its functionality. Below is a detailed breakdown of the block diagram, which divides the system into the following functional blocks:

Waste Detection System
The waste detection system is responsible for identifying the type of waste (wet or dry) based on the readings from IR Sensor (for dry waste) and Rain Sensor (for wet waste)

Microcontroller ESP32
The ESP32 microcontroller serves as the brain of the system. It is responsible for receiving input data and signals from the sensors, processing the data also controlling the actuators (servo motor) and also communicating with the cloud- based platform for monitoring.

Servo Motor
The servo motor controls the waste compartment door, directing waste into either the wet or dry compartment based on detected waste type

Ultrasonic Sensor
The ultrasonic sensor measures and gives the distance between the sensor, the top surface of the waste in the bin for determining the fullness level.

GPS for location tracking
The GPS module tracks the geographical location (latitude and longitude) of the waste bin in real-time

Cloud Communication through Blynk app
The Blynk cloud platform acts as a central hub to process and visualize the data got the sensors. It enables remote monitoring and interaction with the system through the Blynk mobile app.

Alert System
The buzzer serves as an alert system for the user and waste management team

Rain Sensor
The rain sensor detects the presence of wet waste. It is connected to GPIO 15. When the sensor detects moisture (wet waste), it sends a LOW signal to the ESP32

Software Implementation
The software implementation for the Smart Waste Dustbin System involves integrating the hardware components (sensors, actuators) with the microcontroller (ESP32) and using a cloud-based platform (Blynk) for real-time monitoring and control. The software is written in Arduino IDE using C++ programming language and communicates with the ESP32, utilizing libraries like Blynk, ESP32Servo, Tiny GPS++, and Wi Fi.

The first section of the code includes the necessary libraries and sets up the required credentials for Wi-Fi and Blynk. Using credentials one can log in and manage the portal. A mobile app that is available offline could provide users with access to help and locate areas, expanding the platform's reach.

4. CONCLUSIONS AND FUTURE WORK

Future Enhancements for the Smart waste dustbin

The Smart Waste Dustbin system designed for automated waste detection, sorting, and monitoring has significant potential for expansion and enhancement in the future. In this section, we can discuss the possible improvements and future scope of system, as well as the challenges that need to be addressed for broader implementation cases as needed. Integration with Smart City Infrastructure one of the major areas for future development lies in integrating the Smart Waste Dustbin system with broader Smart city infrastructure. Smart cities rely on interconnected systems that use data to improve the quality, efficiency of life for residents and optimize city services. The Smart Waste Dustbin system can be integrated with Various IT System of the cities.

Improved waste sorting Technologies

Although the present system effectively sorts dry and wet waste, future advancements in AI-based waste sorting could make it more intelligent and capable of handling a wider variety of waste types.

Expansion to handle more complex waste

The present system primarily handles simple waste categorization into wet and dry types. However, with ongoing advancements in material science and waste processing, the system could evolve to manage more complex types of waste

Enhancement in Sensor Technology

The performance and quality of the current system is heavily dependent on the sensors used for waste detection (IR sensor, rain sensor, ultrasonic sensor). To improve the system's accuracy and performance, the sensor advancements could be incorporated

Mobile Application Development

The platform's accessibility and usability would be enhanced by developing a mobile application specifically for it. A mobile app that is available offline could provide users with access to help and locate areas, expanding the platform's reach.

Integration with renewable Energy Sources

To enhance the sustainability of the Smart Waste Dustbin system, future versions could be powered by solar panels or other renewable energy sources. This would make the system more energy-efficient and reduce its reliance on traditional power sources, especially for outdoor or remote installations

Expansion to Autonomous Waste Collection Systems

As the system matures, it could be integrated with autonomous waste collection robots for fully automated waste management

Working with NGOs

It is possible that establishing an efficient communication channel between the platform, law enforcement agencies and NGOs could enhance its ability to handle cases. The provision of anonymous incident details to authorized organizations could facilitate faster and more coordinated response to Waste Collection

Recurrent Community survey and responsive feedback integration

A feedback mechanism could be implemented, enabling users to share their experiences and suggestions for ongoing enhancement. This would ensure continuous improvement. The platform could be able to adapt and keep pace with changing user preferences due to frequent community surveys that provide insight into new trends.

Blockchain for Secure Access

The technologies of Blockchain will be used for access, manage register, sign in, log in and keeps credentials Secure

Integrating with Environmental Managing Systems

The platform, and possibly by Integrating to Environmental management authorities and Solid waste management authorities one can track the level of bin

Global adoption in developing countries

While the systems areideal for urban environments in developed countries it has significant potential for deployment in developing countries where waste management was a major challenge. By introducing low-cost, low-maintenance smart waste systems, local municipalities

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