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GARBY: An Autonomous Garbage Disposal and Profiling System with Smart Scheduling

Kathea V. Bolivar, Kryzl V. Deceo, Yvan Caesar M. De Guzman, Mary Glynes A. Galilea, Deanddra F. Robles, Louie Jay L.Sombito, Rosalyn S. Garde

College of Engineering, University of Saint La Salle, La Salle Avenue, Bacolod City, Negros Occidental, Philippines

ABSTRACT

Rapid urbanization and population growth have significantly increased the demand for efficient waste management systems. This study presents an autonomous garbage disposal and profiling system with smart scheduling aimed at improving waste collection efficiency and data-driven decision-making. The proposed system consists of an autonomous dual-compartment garbage bin and a stationary main receptacle, enabling the segregation and profiling of biodegradable and non-biodegradable waste. The autonomous bin navigates predefined routes and disposes collected waste based on height thresholds, scheduled intervals, or manual override. System status, including bin capacity and battery level, is monitored through a mobile application, while waste profiling data are stored on a web server accessible to local authorities. Smart scheduling is implemented using machine learning, where disposal frequency data are analyzed to predict when the main receptacle will reach its capacity threshold. Results demonstrate the feasibility of integrating autonomous collection, waste profiling, and predictive scheduling into a unified smart waste management system suitable for controlled urban environments.

KEYWORDS

arduino, data management, raspberry pi, trash

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Solid waste management remains one of the most critical challenges in both small and large cities in developing countries (Geetha and Rajalakshmi, 2020). With the continuous growth of global population and urbanization, waste generation has steadily increased, reaching 2.01 billion tons of municipal solid waste in 2016, with an average of 0.74 kg per person per day, and is projected to rise to 3.4 billion tons by 2050 according to the World Bank (Kaza et al., 2018). In the Philippines, improper garbage disposal persists as a major environmental issue, with annual waste generation increasing from 14.66 million tons in 2014 to 18.05 million tons in 2020, driven by rapid population growth, economic development, and urbanization. Municipal solid waste, which includes biodegradable and non-biodegradable materials, is typically collected manually by Local Government Units (LGUs) in compliance with Republic Act No. 9003, or the Ecological Solid Waste Management Act of 2000 (Beltran, 2001); however, more than two decades after its enactment, improper disposal, overflowing bins, irregular collection schedules, and stagnant waste at collection points remain prevalent. Previous studies have shown that traditional waste collection systems struggle to cope with increasing demand and may pose environmental risks, while the application of Industry 4.0 technologies—such as smart bins, automation, data analysis, and machine learning—can enhance waste collection efficiency, waste profiling, and scheduling (Bányai et al. 2019; Naresh et al. 2020; Malapur and Pattanshetti, 2017; Asyikin, 2020).

***Corresponding author:**
Rosalyn S. Garde
University of Saint La Salle
La Salle Avenue, Bacolod City
r.garde@usls.edu.ph

Building on these concepts, this study presents an autonomous garbage disposal and profiling system using an Arduino- and Raspberry Pi–based architecture composed of mobile garbage bins and a stationary main receptacle, designed to reduce human intervention, improve collection efficiency, and generate waste profiles to support data-driven scheduling and informed decision-making by LGUs.

This study aims to develop a system that will modernize the current way of collecting garbage in residential areas. The garbage bin will autonomously go to the main garbage receptacle when one of the triggers is prompted. For the system, the line follower method was used by the garbage bin to direct its path from the user's home to the main garbage receptacle and return back home. The system that was developed was a scaled down version of an actual garbage bin and main receptacle.

The study deals with both qualitative and quantitative data that will be gathered after developing the autonomous garbage disposal system with the use of a series of trials done to ensure that the system works as intended. The study gathered data that determined the performance of the garbage bin and main receptacle. The series of trials were based on the accuracy of the garbage bin at different distances that it covered to reach the main receptacle.

The main garbage receptacle is capable of profiling the weight of each type of garbage (i.e. biodegradable and non-biodegradable). The garbage profiling was tested to check if the data collected and sent to the authorities by the main receptacle was correct. This was done by changing the weights of the garbage in the main receptacle and checking if the gathered or sent data showed the same amount. The frequency of discarding the garbage was tracked and used to analyze when the main garbage receptacle reached its threshold capacity.

The system was developed through the design and fabrication of a scaled prototype consisting of two autonomous mobile garbage bins and a stationary main receptacle. The bins were fabricated using acrylic material, while the main receptacle was constructed from plywood, with all components integrated and wired to their respective microcontrollers. The garbage bins were controlled by an Arduino Mega, while the main receptacle was managed by a Raspberry Pi, with sensors and actuators connected to enable autonomous operation, monitoring, and data processing. Each mobile bin featured dual compartments for biodegradable and non-biodegradable waste and utilized infrared sensors for line-following navigation, RFID-based route identification, ultrasonic sensors for capacity detection, and motor drivers for movement control. The main receptacle incorporated load and ultrasonic sensors to profile waste weight and capacity. A closed intranet architecture was implemented to coordinate system polling, triggering disposal based on capacity thresholds, scheduled intervals, or manual user commands. A mobile application was developed to monitor bin status and enable manual overrides, while a web server stored waste profiling data accessible to local authorities. Machine learning was applied to analyze disposal frequency and predict receptacle fill times for smart scheduling. System functionality was evaluated through repeated trials assessing navigation, triggering mechanisms, waste profiling accuracy, alert protocols, and communication features, including SMS and email notifications for collection and fault conditions.

The system, which includes the garbage bins and the main receptacle, has been assembled and tested with consideration of different triggers as well as showcasing the features of the system.

The system operates as an automated waste collection network in which two smart bins communicate with a central controller located in the main receptacle via a closed WLAN. A Raspberry Pi continuously polls all bins at regular intervals of approximately 300 seconds plus network delay, serving as the core decision-making unit. At the start of each polling cycle, the system first checks whether a manual override has been activated through a latching button; if so, all operations are paused until the issue is resolved or waste is collected. If no override is active, the system evaluates three disposal triggers in sequence: scheduled disposal (based on a predefined time), full bin detection, and manual disposal requests initiated through a mobile application. Any bins meeting these conditions are queued and processed one at a time before the system loops back to repeat the cycle.

When a bin is triggered for disposal, it follows a standardized disposal sequence. The smart bins autonomously travel from its station to the main receptacle using line-following logic, during which communication is temporarily disabled to prevent interference. RFID tags embedded along the guided navigation by indicating turns, stops, and task points such as waste dumping and return positioning. Ultrasonic sensors enable obstacle detection, causing the bin to pause until the path is clear, though this delay counts against a three-minute timeout window. Once the bin reaches the receptacle, it disposes of its contents and returns to its home position, after which the next queued bin begins its sequence. If a bin fails to return within the allotted time or encounters an issue, the system activates a “Help Me” protocol that sends an SMS alert to the user and allows location tracking via GSM upon request.

After each disposal, the main receptacle evaluates its current waste level and weight using load cells and ultrasonic sensors. If the receptacle is not yet full, a simple machine learning approach analyzes historical data to predict when it will reach capacity, using the most frequent earliest time of full-capacity occurrences as a basis for confidence. If the receptacle is full, the system immediately notifies local authorities through SMS and email services. Users interact with the system through a Flutter-based mobile application, which provides real-time monitoring of bin capacity and battery levels and allows manual disposal requests via Firebase. Additionally, a web server enables local government units to access detailed waste data, including timestamps, waste classification, and weight, downloadable as regularly updated CSV files.

Operational safeguards ensure reliability and efficiency across various scenarios. Bins are prevented from operating when the main receptacle reaches a critical threshold (e.g., 90% capacity), and the manual override feature can halt the entire system during maintenance or emergencies while simultaneously notifying authorities. Sequential processing and built-in delays ensure that a malfunctioning bin does not disrupt the entire system, while users retain the flexibility to trigger disposal even below threshold levels. Hardware responsibilities are distributed between Arduino-based GARBY units, which manage movement, sensing, and dumping mechanisms, and the Raspberry Pi in the main receptacle, which oversees system logic, communication, and data processing. Overall, the system combines autonomous navigation, centralized control, IoT communication, and predictive analytics to deliver an efficient and responsive waste management solution.

Figure 1. Prototype of the Garbage Disposal and Profiling System.

Tables 1 and 2 show the different types of trials conducted on Garbage Bins 1 and 2 respectively. The height and schedule trigger as well as the manual override underwent 10 trials. The height trigger has 80% success rate. The 20% failure rate is due to incomplete disposal of biodegradable materials. The manual override feature on the other hand had a 90% success rate. The 10% failure rate is due to the failure to fully dispose of the non-biodegradable material. The reason for the failure on both types of trials is that the garbage got stuck in the bin due to its scaled down dimensions. The rest of the types of trials indicated 100% success rates which proved that the system is reliable.

Table 1. Performance Assessment of Control and Detection Features for Garbage Bin 1

Type of trial	Successful trials	Failed trials	Total number of trials	Remarks
Height Trigger	8	2	10	Bio not fully disposed
Scheduled Trigger	10	0	10	No error occurred
Manual Override	9	1	10	Non-bio not fully disposed
“Help Me” Protocol	5	0	5	Garby Successfully Located
Obstacle Detection	5	0	5	All obstacles detected
Location Tracking	5	0	5	Similar Location Detected

Table 2. Performance Assessment of Control and Detection Features for Garbage Bin 2

Type of trial	Successful trials	Failed trials	Total number of trials	Remarks
Height Trigger	8	2	10	Bio not fully disposed
Scheduled Trigger	10	0	10	No error occurred
Manual Override	8	2	10	Not all garbage disposed; Line follower error
“Help Me” Protocol	5	0	5	Garby Successfully Located
Obstacle Detection	5	0	5	All obstacles detected
Location Tracking	5	0	5	Similar Location Detected

Table 3 shows the results for the 10 trials done on the main receptacle. It provided a 100% success rate for all types of trial.

Table 3. Performance Assessment of Control and Detection Features for Main Receptacle

Type of trial	Successful trials	Failed trials	Total number of trials	Remarks
Height Trigger	10	0	10	No error occurred
Set Scheduled Trigger	10	0	10	No error occurred
Manual Override	10	0	10	No error occurred
Smart Schedule Trigger	10	0	10	No error occurred

Table 4 shows the results for the trials that were conducted for the main garbage receptacle smart schedule trigger. The researchers tested if the receptacle sends the SMS and email when the confidence level of a prediction that the receptacle would be full reaches 90%. Results show that for all the trials, it has predicted that the bin would be full in the next two hours upon receiving the forecast notification.

Table 4. Main Receptacle Trials for Smart Schedule Trigger Function

Trial	Trigger	SMS	Email	Remarks
1	success	received	received	Forecasted schedule sent 2 hours prior to the predicted schedule
2	success	received	received	Forecasted schedule sent 2 hours prior to the predicted schedule
3	success	received	received	Forecasted schedule sent 2 hours prior to the predicted schedule
4	success	received	received	Forecasted schedule sent 2 hours prior to the predicted schedule
5	success	received	received	Forecasted schedule sent 2 hours prior to the predicted schedule
6	success	received	received	Forecasted schedule sent 2 hours prior to the predicted schedule
7	success	received	received	Forecasted schedule sent 2 hours prior to the predicted schedule

Figure 2 shows the SMS Alert that the user will receive should there be problems encountered by the Garbage bins while travelling from the location to the main receptacle. It shows the location of the bins through the use of GPS.

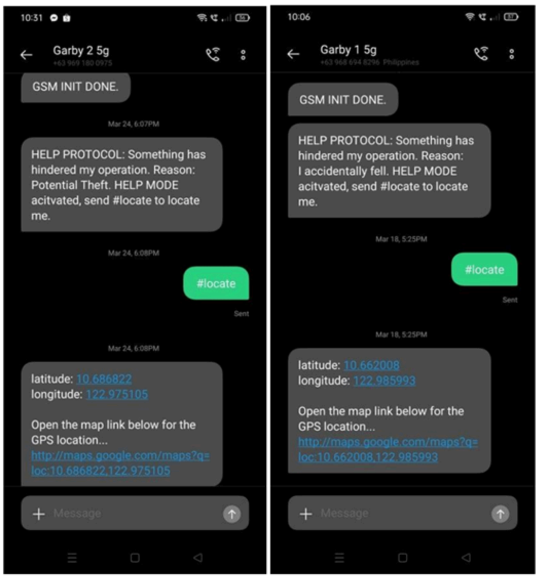

Figure 2. SMS Alert for the Help Protocol Function.

This study demonstrated the feasibility of an autonomous garbage disposal and profiling system capable of delivering waste to a central receptacle using height-based, scheduled, and manual triggers enabled by integrated sensors and microcontrollers. The developed system successfully generated waste profiles and analytical reports from the main receptacle, which were used to support smart scheduling and informed planning for garbage collection. In addition, real-time system status updates and notifications were effectively communicated to users and local authorities through SMS and email, enhancing monitoring and responsiveness. Overall, the results indicate that integrating autonomous collection, waste profiling, and predictive scheduling can improve the efficiency and reliability of waste management in controlled urban environments. Future work may focus on incorporating sustainable energy sources such as solar power, integrating self-sanitation mechanisms to further reduce human intervention, and implementing real-time tracking through mapping services to enhance system scalability and operational robustness.

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AUTHOR CONTRIBUTIONS

- **Kathea Bolivar and Mary Glynes Galilea:** Documentation and writing the final paper
- **Kryzl Deceo and Yvan De Guzman:** Prototype fabrication, testing and evaluation
- **Deanddra Robles and Louie Jay Sombito:** Software development
- **Rosalyn Garde:** Supervision and journal writing

CONFLICT OF INTEREST

The Authors declare no conflict of interest.

ETHICS STATEMENT

All research has been conducted in accordance with the ethical principles and guidelines.

REFERENCES

Asyikin, A. (2020). Design and Implementation of Different Types of Smart Dustbins System in Smart Campus Environments. International Joint Conference on Science and Engineering (IJCSE 2020), Volume 196. Atlantis Press.

Bányai, T., Tamás, P., Illés, B., Stankevičiūtė, I., & Bányai, G. (2019). Optimization of Municipal Waste Collection Routing: Impact of Industry 4.0 Technologies on Environmental Awareness and Sustainability. International Journal of Environmental Research and Public Health, 16(4), 634. https://doi.org/10.3390/ijerph16040634

Beltran, J. (2001). Republic Act No. 9003, “The Ecological Solid Waste Management Act Of 2000”. https://r12.emb.gov.ph

Geetha, R., & Rajalakshmi, S. (2020). Problem faced by the public due to the improper waste disposal and behavior of waste disposal. International Journal of Social Sciences and Management, 7(2), 70–77. https://doi.org/10.3126/ijssm.v7i2.28593

Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). What a Waste 2.0: A global snapshot of solid waste management to 2050. World Bank. https://doi.org/10.1596/978-1-4648-1329-0

Malapur and Pattanshetti (2017). IoT based waste management: An application to smart city. Conference: 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS). DOI:10.1109/ICECDS.2017.8389897

Naresh, R., Meenakshi, M., & Niranjana, G. (2020, January). Efficient Study of Smart Garbage Collection for Ecofriendly Environment. Journal of Green Engineering, 10(1). http://www.jgenng.com/wp-content/uploads/2020/02/volume10-issue1-01.pdf