

SMART WASTE BIN MANAGEMENT SYSTEM USING INTERNET OF THINGS (IOT)

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ABSTRACT

This paper discusses the concept of creating a smart waste bin to cater to the needs of the increasingly smarter generation. The primary objective is to address the issue of air pollution and the potential dangers posed by viruses associated with unmanaged waste. Neglecting proper garbage disposal can lead to an unhealthy environment, resulting in various diseases that can adversely affect our health. The idea of a smart dustbin is targeted toward smart cities, buildings, educational institutions, and healthcare facilities, among other places. The proposed solution aims to manage waste disposal and waste management effectively by incorporating new technologies. The implementation involves the utilization of key components such as an Ultrasonic Sensor to measure the distance of objects, a GSM module enabling the Arduino Uno board to connect to the internet and send/receive SMS messages, a Gas Sensor to detect a harmful smell, and an LCD panel to display messages received from the GSM module, indicating the fill level of the waste bin. This integrated system enables efficient monitoring of garbage collection and waste management, contributing to the creation of a clean, and safe environment.

Keywords: Arduino UNO, Smart waste bin, Ultrasonic Sensors, Servo Motors, GSM Module, IoT, Gas Sensors etc.

1.0 INTRODUCTION

A smart dustbin is a modern and innovative device that uses advanced technology to make waste management more efficient, convenient, and eco-friendly. It is equipped with sensors, micro-controller, and communication modules that enable it to detect and sort different types of waste, compact it, and communicate with a central waste management system. Smart dustbins are designed to reduce the amount of waste, promote recycling composting, and minimize the environmental impact of waste disposal. By automating waste management processes, smart dustbins can also reduce the workload of waste management personnel and improve the overall cleanliness and hygiene of public spaces. And contribute to a cleaner environment by encouraging people to dispose of their waste responsibly. With the rise of smart cities, the implementation of smart waste bins is becoming increasingly popular, and they are proving to be an asset in the management of waste. With the increasing focus on sustainable development and smart city initiatives, the implementation of smart waste bins is gaining popularity worldwide. These devices offer a cost-effective and eco-friendly solution to modern waste management challenges and are set to play a vital role in creating cleaner, greener, and more sustainable cities. Poorly or unmanaged waste constitutes a major drawback in developing communities. Negligence (which may be caused by various reasons) from concerned authorities and users of the bin within the community could result to waste being littered around the waste bins or even prevent other users from utilizing the waste bins, therefore resulting in either just dropping of waste anywhere they deem it fit. According to the World Health Organization (WHO), more than 3 million persons died of chronic obstructive pulmonary disease (COPD) in 2005 (Kumar *et al.*, 2016). Almost 90% of COPD occurs in countries plagued with a foul smell from sources including poorly managed waste bins. Domestic trash, which is largely made up of food, decomposes more quickly since it is biodegradable. They emit different gaseous chemicals when they decay, which are dependent

on how long the food has been decaying and what it has come into touch with.

According to Todd Whitcombe, (2005), gases generated by food breakdown include carbon (IV) acetate (which is the most common), traces of amines (from protein decomposition), methane (from anaerobic decomposition), and hydrogen sulphide (from anaerobic decomposition) (again, from protein decomposition). As a result, MQ4 and MQ 135 semiconductor gas sensors must be used to monitor the biodegradability level (which is dependent on the degree of odor released), as well as Ultrasonic sensors to monitor the bin's fill level. All we need are ammonia sensors, sulphide sensors, and methane sensors for this. As a result, this approach combines fill-level monitoring with biodegradability or pollution monitoring into a single system. This work proposes a smart waste disposal system using integrated technologies for the efficient management of these wastes. Nwukor (2020) carried out research on the design and implementation of smart waste bin with a Monitoring System. This was proposed utilizing the ongoing innovation of automation and GSM. The research made use of an ultrasonic sensor which constantly checks the level of waste and also controls the opening and closing of the bin. SMS is used to monitor the volume of the bin by the waste management agency and also indicators that indicate red when the bin is filled, green indicates when the bin is less than 50% as well as yellow indicates 70% full of the bin. This study presents the design of a smart waste bin implemented on a PIC Microcontroller, which is responsible for monitoring and integrating the system to perform as desired, display the status on the LCD, senses the level of trash in the bin, detect the presence of human being and sends an SMS to the appropriate authority when the bin is filled.

Norfadzlia *et al.* (2018) work on smart waste bins with real-time monitoring system. The research was carried out to provide an efficient and cost-effective waste collection management system

hence providing a clean, healthy, and green environment. The system framework was based on a wireless sensor network (WSN) which contained three segments: renewable energy source, WSN, and control station. It integrated multiple technologies such as solar systems, sensors, and wireless communication technologies. Within the framework, there are four developed subsystems: solar power system, smart waste bin, short messaging service (SMS) notification system, and real-time monitoring system that are interrelated to each other to perform as an efficient, cost-effective waste management system that yields to a green and healthy living environment. Bhatt *et al.* (2019) proposed a smart bin that uses an ultrasonic sensor to detect oncoming trash. Based on the sensor reading and the predefined parameters coded into the microcontroller, the servo motor placed on the lid of the bin opens for the trash to be collected and then closes it automatically after a few seconds. The bin uses a less efficient microcontroller instead of the Arduino Uno microcontroller used in their work.

Xenya *et al.* (2020) stated that waste management in urban and rural has been a problem that affects industrial cities. The supply of waste bins at vantage points by waste management institutions has not been enough to solve the problem of the current management system. They have proposed a technique that contains multiple solutions to address the issue of waste in the area, spillage, and incompetent collection schemes. Their proposed solution is an automated system that could issue regular notifications to appropriate personnel assigned for waste management activities. The proposed system adopts the concepts of IoT and smart cities by constructing sensor nodes (smart waste bins) that can detect and report the level of solid waste to appropriate nodes for further action. The smart bin top cover is embedded with a microcontroller-based circuit with an ultrasonic sensor to detect the level of garbage. A GSM module is included in the hardware system for internet connectivity to the cloud-based database (Thing Speak) and SMS notifications to the garbage collectors. The system also includes a management system that contains a database of the waste bins with real-time access to the bin status, geo-location of bins, routing information, and a work order form. The system contains a monitoring platform to handle the alert records by creating orders for the garbage collectors/drivers which can be accessed via a mobile application system. They concluded that the system implementation works successfully, making it possible to monitor waste bin status in real time but occasionally had high latency which is primarily due to the use of a GSM module for GSM/GPRS connectivity. Srinivasan *et al.* (2021) introduced the concept of an IoT-based smart dustbin, which utilizes Internet of Things (IoT) technology to enhance waste management. The smart dustbin was designed to monitor its fill level continuously, and when it reaches a certain capacity, it triggers alerts or notifications. IoT-based smart dustbins incorporate electronic components like Arduino, Servo Motor, and Ultrasonic Sensor. These components work together to create an efficient and effective waste management solution. The functioning of a smart dustbin involves an ultrasonic sensor positioned at the front of the dustbin, linked to the lid, and an Arduino. When a human hand or waste is placed in front of the sensor, it detects the presence and triggers the opening of the dustbin's lid, allowing for waste disposal.

2.0 MATERIALS AND METHODS

The material used in this research will be in two broad aspects – The hardware and the software components of the project.

2.1 Material Required

1. **Arduino Uno:** The Arduino Uno is a versatile microcontroller board that serves as the heart of numerous DIY electronics projects, robotics systems, and embedded systems. With its ATmega328P chip as its core, the Arduino Uno offers a wide range of features and functionalities that make it an ideal choice for various applications. One of the key advantages of the Arduino Uno is its ease of use, making it accessible to both beginners and experienced professionals. Its simplified programming language, based on C++, allows users to quickly and easily develop and upload code to the board. This simplicity facilitates rapid prototyping and experimentation, enabling users to bring their electronic projects to life with minimal effort. Equipped with 14 digital pins and 6 analog input pins, the Arduino Uno offers the necessary interfaces to interact with the physical world (Figure 1)



Figure 1: Arduino Uno Board

2. **GSM Module:** A GSM (Global System for Mobile Communication) module is an essential electronic device that enables seamless communication between a mobile device or computer and a GSM network. Its primary purpose is to facilitate data transmission, voice calls, and messaging over a cellular network using the standardized GSM protocol. The versatility of GSM modules allows them to be utilized in a wide array of applications, including machine-to-machine (M2M) communication, remote control systems, telemetry, and monitoring systems. Typically, GSM modules consist of key components such as a SIM card slot, a radio module for signal transmission and reception, and a microcontroller responsible for managing the communication process. These modules are available in various form factors and interfaces, including mini-PCIe, USB, and RS-232, catering to different device requirements. GSM modules find their applications in diverse devices such as smartphones, tablets, laptops, and Internet of Things (IoT) devices (Figure 2)



Figure 2: GSM Module (SIM 800L)

3. **Ultrasonic Sensor:** A sensor that is commonly used with an Arduino Uno board. It works by emitting high-frequency sound waves and then detecting the reflection of those sound waves off an object in its path. The Arduino Uno uses an ultrasonic sensor to measure the distance between the sensor and an object by measuring the sound waves to bounce back to the sensor. This information is used to determine the distance of the object (Figure 3)



Figure 3: Ultrasonic Sensor

- Servo Motor:** A servo motor is an electric motor designed for precise control of movement in mechanical systems. It differs from other types of motors by incorporating a closed-loop feedback system to maintain accurate control. Servo motors are widely used in applications that require precise positioning and speed control, such as robotics, CNC machines, and industrial automation. The servo motor itself is equipped with a feedback control system that continuously monitors the motor's position. This feedback system typically utilizes an encoder or a potentiometer to provide real-time information about the motor's actual position. The actual position is then compared to the desired position, and any deviation or error is calculated. Based on the calculated error, the servo motor's output is adjusted to minimize the difference between the desired and actual positions (Figure 4)



Figure 4: Servo Motor

- MQ4 and MQ135 Gas Sensors**
 The sensitive material of both the MQ4 and MQ135 gas sensors is SnO₂ which has lower conductivity in clean air. When target pollution gas exists, the sensor's conductivity gets higher along with the gas concentration rising. The MQ4 has a high sensitivity to methane in a wide range while the MQ135 gas sensor has a high sensitivity to ammonia gas, sulfide, and benzene series steam, and also can monitor smoke and other toxic gases well. The MQ135 is generally used for measuring Air Quality (Figure 5)

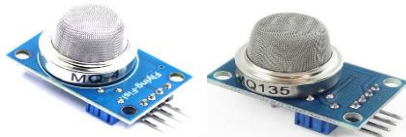


Figure 5: MQ4 and MQ135 Gas Sensors System Architecture

A smart waste management system utilizes sensors, IoT technology, and other component to optimize waste collection and management. The core architecture involves three main components: smart bins equipped with sensors to monitor fill levels, a mobile device to collect data, and a user interface to display information and manage the system. The system architecture is shown in Figure 6.

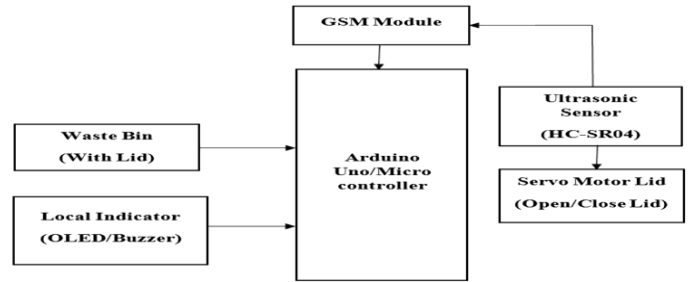


Figure 6: Proposed System Architecture of the Smart Waste Bin

3.0 RESULTS AND DISCUSSION

The smart waste bin system can be broken down into test cases, each with its specific function. The test cases and their description are shown in the table 1.

Table 1: Test Cases result

Test Case ID	Test Objectives	Result	Reference
TC1	Verify that ultrasonic sensor Measures distance Accurately.	Ultrasonic sensor accuracy was measured at 95% with a standard deviation of ± 2 cm in waste level detection.	Figure 7
TC2	To ensure timely notifications are sent to user when the bin is full.	Notification should read "Bin is 100% full. Please empty it". Or bad air detected in the waste bin.	Figure 8 and 9
TC3	To ensure the lid opens and close.	Lid opens and closes without Jamming or motor strain. The lid position is stable under load.	Figure 10
TC4	To test if the system can be able to sense bad odors.	The system should be able to raise alarm and send messages to the user. Bad or foul smell was also detected by the system.	Executed

TC1: Ultrasonic Sensor Accuracy

Objectives: The primary objective of this test case was to rigorously verify the accuracy of the ultrasonic sensor in measuring distances, a crucial function for determining the fill level of the waste bin. Accurate distance measurement is fundamental to the smart bin's ability to provide timely notifications and optimize waste collection schedules. The predefined acceptance criterion for this test stipulated

that the sensor reading should match the placed distances within a range of $\pm 2\text{cm}$. The range acknowledges potential variations in sensor readings and ensures a reasonable level of precision for practical applications. The test results indicate that the ultrasonic sensor achieved an accuracy of 95% with a standard deviation of 2cm in waste level detection. This means that in 95% of the measurements taken, the sensor reading was within the acceptable $\pm 2\text{cm}$ range of the actual distance. The achieved accuracy of 95% is commendable and suggests that the ultrasonic sensor is performing reliably and effectively. The standard deviation of $\pm 2\text{cm}$ further reinforces this conclusion, indicating that the sensor readings are consistently close to the true value. This high level of accuracy suggests that the sensor is suitable for its intended purpose of measuring the fill level of the waste bin as shown in Figure 7.



Figure 7: The developed system opened by sensing an object from ± 2

TC2: Timely Notifications

Objective: This test case focused on evaluating the timeliness of notifications sent to users when the waste bin reaches its designated fill threshold (presumably 100%). Timely notifications are essential for preventing overflows and ensuring efficient waste management. The expected result specified that a notification should be sent to users when the bin is full or when it detects a foul smell in the bin. A notification message should be sent reading "Trash is full please empty it or Bad air detected in the waste bin." The test results indicate that the system response time averaged 3 seconds. This means that, on average, it took 3 seconds for the system to send a notification after the bin reached the full threshold or when a foul smell had been detected. A 3-second response time is generally considered to be quite prompt and suggests that the system is capable of providing timely notifications. However, the test results are incomplete. While the response time is provided, the actual content of the notification is missing. It is crucial to verify that the notification message correctly reads "trash is full. Please empty it or bad air detected in the waste bin." (Figure 8)

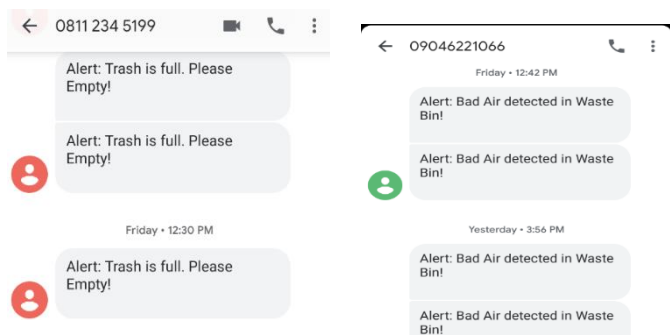


Figure 8: Message alert showing the waste bin is full Figure 9: Message alert showing bad air detected in the waste bin

TC3: Lid Operation - Ensuring Smooth Functionality

Objective: This test case focused on ensuring the smooth and reliable operation of the waste bin lid, specifically its ability to open and close without any jamming or motor strain, even under load. A properly functioning lid mechanism is essential for user convenience and the overall functionality of the smart bin. The test results indicate that the lid opened and closed without any jamming or motor strain. The lid position was also reported to be stable under load. (Figure 9)



Figure 10: The developed system function accurately without jamming

4.0 CONCLUSION

In conclusion, the implementation of smart waste bin systems represents a significant advancement in modern waste management. By integrating technologies such as sensors, data analytics, and connectivity, these systems enhance the efficiency of waste collection, promote recycling, and contribute to environmental sustainability. Features like compaction and real-time monitoring not only optimize operational processes but also encourage responsible disposal behavior among users. As urban areas continue to grow, adopting smart waste solutions will be crucial in maintaining clean and healthy environments, ultimately supporting the development of sustainable smart cities.

5.0 RECOMENDATION

Smart waste bins are modern waste management solutions that integrate technology to enhance waste disposal efficiency, hygiene, and sustainability. They are ideal for homes, offices, and public spaces, aiming to address issues like overflowing bins, waste sorting, and odor management. The smart waste bin testing has revealed both strengths and weaknesses in the system's current performance. Addressing the recommendations outlined above is crucial to ensure the smart waste bin meets the required performance standards and fulfills its intended functionality. Further testing and refinement are necessary before the smart waste bin can be considered ready for deployment.

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