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Research paper

Real-Time Dustbin Using Gas Sensor, Ultrasonic Sensors, and A GSM Module

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Abstract

Waste management has become a crucial problem to be concerned about because the amount of garbage has increased. Hospitals, offices, and communities can avoid trash overflow by implementing real-time waste containers. As a result, the researcher set up technology for monitoring garbage, which improves community hygiene and garbage pickup efficiency. The system consists of a container, a microcontroller to manage the entire process, two ultrasonic sensors to unlock the dust bin and measure the amount of garbage, a gas detector to detect pollution and smoke, a servomotor to open the dust bin without touching it, and a GSM module to send messages regarding the dust bin's level. The statistical indices' sensitivity, specificity, and accuracy, which are about 93.333%, 93.333%, and 94.791% sequentially for two scenarios with two rounds, are used to apply the experimental results. Subsequently, numerous sensing elements could be combined with the ultrasonic sensor to achieve results that are more accurate.

Keywords: *Sensitivity; Specificity; Accuracy; GSM Model; Ultrasonic Sensor; Microcontroller; Servomotor.*

1. Introduction

Reducing abandoned waste is effectively accomplished through waste management methods. Unfortunately, these techniques are not widely employed in many countries. Whenever it comes to appropriate garbage disposal, numerous people have been careless, disobeying instructions and tossing recyclables that can be reused. Garbage is made of unwanted items that have been dropped in cities, public spaces, societies, colleges, homes, etc. The internet and its applications are now essential components of modern human existence. It is now a necessary tool in every context. Cities that want to reduce costs and better manage resources and time need smart trashcan systems [1]. Managing waste is a crucial issue in urban areas, and technology has come up with ingenious solutions to optimize waste collection operations. It is a well-known fact that bacterial and viral illnesses can develop in a polluted environment. In the past few years, there has been a significant rise in the construction of flats and apartments due to the increasing demand for housing in fast-developing cities. However, the occupants of these apartments face several challenges, including waste disposal. Unlike individual houses, residents of apartment complexes must share a single trash can that fills up quickly. Overfilled garbage cans can be a breeding ground for diseases like cholera and dengue fever. To tackle this problem, the smart dustbin is an innovative solution that can reduce waste accumulation in apartment complexes, if not eliminate it [2].

A review suggests an affordable and user-friendly smart dustbin monitoring system (SDMS) based on Arduino and Wi-Fi modules. This technique centralizes and tracks trash in trash containers, reducing overflow and infections caused by nearby trash [3]. A Raspberry Pi with a machine-learning model to identify waste types and display them on a screen. This innovative design benefits society by demonstrating proper waste disposal in various locations, such as suburban streets, shopping malls, industrial regions, schools, and hospitals. By demonstrating proper waste disposal, the model can help society [4]. A lid-opening trash system based on the Arduino Uno is designed for intelligent dust control and removal. This technology is commonly used to clean buildings and maintain a clean environment. It can be improved by being connected to the cloud and sending alerts when the system is full [5]. Also, an Arduino Uno is used to create a smart trash bin with an ultrasonic sensor HCSR04 for optimal work conditions. The prototype aims to assess waste management issues and evaluate the advantages and disadvantages of smart trash. It involves developing and simulating the prototype using SolidWorks software [6]. A robotic garbage that the user could manage, the voice-controlled dustbin by speaking predefined orders. The voice module processes the speech once it is picked up by the Android device's microphone. To assist the elderly and the crippled, the creator of this article attempted to create a portable garbage can that could be controlled by a cell phone [7]. Furthermore, a proposed automatic intelligent dust bucket aims to provide secure and sanitary trash disposal without human interaction. However, it has limitations, as only one type of waste can be separated at a time, with metal receiving priority. Improvements are needed for the separation of mixed waste types [8]. Intelligent trash cans monitor garbage levels using ultrasonic sensors and GSM modules to transmit data and send messages. When the container is full, intelligent solid waste collecting operations begin. However, dustbins that aren't kept clean may draw insects that carry disease and worsen environmental pollution. Garbage bin air pollution may generate bacteria and viruses that could lead to serious infection [9]. An Arduino Uno is used in a self-driving smart garbage can trolley to measure the amount of trash inside. If the parameters are satisfied or exceeded, the trolley starts, travels to the disposal site using line-follower technology, waits for manual disposal, and subsequently returns to its starting point to begin the next cycle. The trolley stops when an item or person is in its path and resumes motion once they have passed to prevent accidents [10]. An embedded framework using a Wi-Fi modem, IoT, GSM, and ultrasonic sensor has been introduced for efficient waste collection. This system provides an updated database for trash volume and collection frequency at each location, preventing overflow in residential areas. The system sends data to collection vehicles and automatically manages garbage levels [11]. When garbage levels reach the peak, a smart waste monitoring platform with an IR detector, microprocessor, and Wi-Fi module ensures dustbin emptying. If dumpsters are not empty within a predetermined period, reports are forwarded to the appropriate individuals, enabling them to take legal action against the violating establishments. Aforementioned lowers expenses and preserves a clean society by reducing corruption and the number of trips made by garbage collection vehicles [12]. An Internet of Things-based smart trash can with an alarm system that notifies the municipal officials to immediately remove the trash based on the capacity to accept further waste was suggested. Using a PIR (passive infrared) sensing component, which adds the feature of automatically opening and closing the lid when it senses a user's presence. This keeps the user secure and away from potentially dangerous surfaces [13]. Numerous previous studies concentrated on trash containers and approached them from various perspectives in terms of detectors and their different types, as well as communication technologies. A system that keeps the houses, offices, streets, hospitals, and parks cleaner than ever before is being developed. The goal is to construct an alert system that will let us know when a trash bin is full and needs to be emptied. This system will be cost-effective and perfect for small-scale cases like hospitals and university campuses. Maintaining trash bins clean can help prevent littering and keep our communities safe and healthy.

2. Materials and Methods

In this part, it discusses the system formation and layout of the suggested system. The system consists of a gas detector, two ultrasonic sensors, a GSM model, a servo motor, a microcontroller, and a trash container. The system's block diagram is shown in Fig. 1, which can be easily adjusted by including or eliminating input/output components to consider any expectations for advancement in the future. The circuit diagram of the framework is displayed in Fig. 2. The system uses a lithium-ion battery, which is a type of battery that can be charged and stores energy through the reversible elimination of lithium ions [14]. An Arduino UNO [15] is used to control a servomotor [16] that opens the dust bin without touching it, a gas sensor [17] that detects pollution and smoke, and two ultrasonic sensors [18] that detect the person to open the dust bin and the level of garbage.

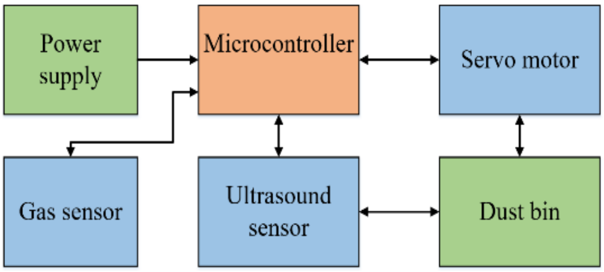

Fig. 1: System Block Diagram.

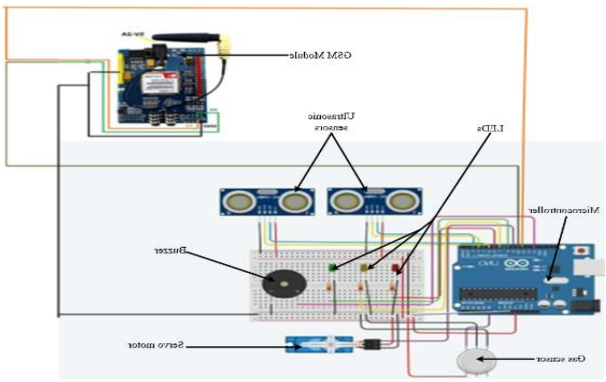

Fig. 2: Schematic of the System.

A GSM model [19] is used in this system to send a message when the dust bin is full to empty and clear it. The Arduino integrated development environment [20] is used to program the system according to specific commands. Fig. 3 shows the Arduino Software, the main site of the program, and Fig. 4 illustrates the message of the GSM model when the dust bin is full or empty.

```
//digitalWrite(ledPinr, LOW);
//}
if (distance2 >= 40) {
   digitalWrite(ledPing, HIGH);
   digitalWrite(ledPiny, LOW);
   digitalWrite(ledPinr, LOW);
 } else if (distance2 >= 15 && distance2 <= 30) {

   digitalWrite(ledPing, LOW);
   digitalWrite(ledPiny, HIGH);
   digitalWrite(ledPinr, LOW);
 } else if (distance2 <= 15){
   digitalWrite(ledPing, LOW);
   digitalWrite(ledPiny, LOW);
   digitalWrite(ledPinr, HIGH);
delay(1000);
}
```

Fig. 3: The Code of the Program.

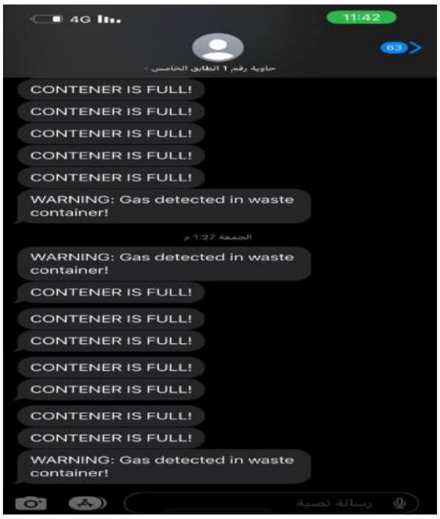

Fig. 4: Message of the Alarm Notation.

The algorithm for the system will be displayed in Fig. 5, which depicts how the platform operates while the power is on. Update the trash level to change the output from the ultrasonic detector. While the dust bin is full, a message will be sent immediately to a qualified individual asking them to empty the bin.

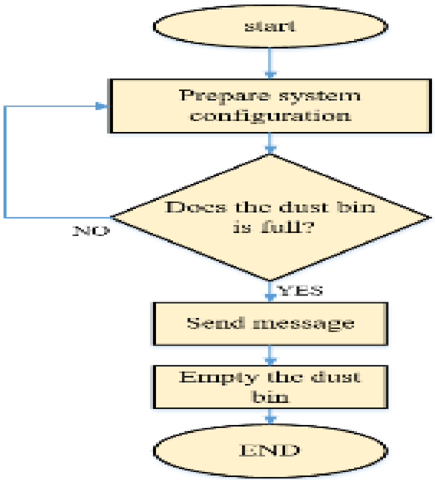

Fig. 5: System Subroutine.

To confirm and testify about the system, three statistical evaluations, namely sensitivity and specificity, have been used. These calculations are established on four indices that have four possible outcomes, namely the true positive (TP), false positive (FP), true negative (TN), and false negative (FN). Table 1 shows the indices and what they represent.

Table 1: The Indices of the Calculations

Indices	Represent
True positive	The motor is ON and the system is active
False positive	The motor is OFF and the system is active
True negative	The motor is ON, and the system is not active
False negative	The motor is OFF, and the system is not active

According to Equation (1) [21-23], sensitivity (SN) describes the capability of the system to carry out its intended purpose. The term "sensitivity" is also used to specify the recall.

$$SN.\% = \frac{TP}{TP+FN} \times 100 \tag{1}$$

The possibility of the system's operation is referred to as specificity (SP), as stated in Equation (2) [21-23].

$$SP.\% = \frac{TN}{TN+FP} \times 100 \tag{2}$$

The F-measure accuracy (overall accuracy) has also been generated to assess performance in general [21-23]. Recall (sensitivity) and precision are combined to form F-measure accuracy, which can be described as follows:

$$\text{Precision } \% = \frac{TP}{TP+FP} \times 100 \tag{3}$$

$$\text{F} - \text{measure accuracy } \% = 2 \times \frac{\text{recall} \times \text{precision}}{\text{recall} + \text{precision}} \tag{4}$$

3. Results and Discussion

The methodology's findings reveal a statistical investigation of the sensitivity and specificity of a verified evaluation of the suggested system. The (TP), (FP), (TN), and (FN) classification approaches were also investigated and presented in Tables 2 to 3. The scenarios are applied repeatedly for two rounds.

Table 2: Sensitivity Results for Test 1

Test 1	Round 1	Round 2
Attempts	15	15
TP	14	13
FN	1	2
Sensitivity (%)	93.3	86.6

Table 3: Specificity Results for Test 2

Test 2	Round 1	Round 2
Attempts	15	15
TN	14	14
FP	1	1
Specificity (%)	93.3	93.3

The system's overall reliability and data are demonstrated in Table 4, with a confusion matrix serving as the expression of accuracy confirmation. With 30 trials conducted across two rounds, the accuracy of the whole evaluation is determined to be 94.791%, calculated using Equations (3-4).

Table 4: Overall Accuracy Confirmation

Parameters	Round 1	Round 2
Total number of experiments	30	30
TP	26	27
FP	1	1
TN	2	1
FN	1	1
Confusion matrix= **TP FN** **FP TN**	26 1 1 2	**27 1** **1 1**
Precision (%)	96.296	96.296
Recall (%)	93.333	93.333
Overall accuracy (%)	94.791	94.791

The results indicate that the trash can is monitored by an uncomplicated circuit and that people are immediately reminded to empty the bin to prevent an accumulation of trash in the container, which helps keep the environment clean and healthy. The system is reasonably priced and simple to maintain, as shown by the components and circuit connection in Fig. 6.

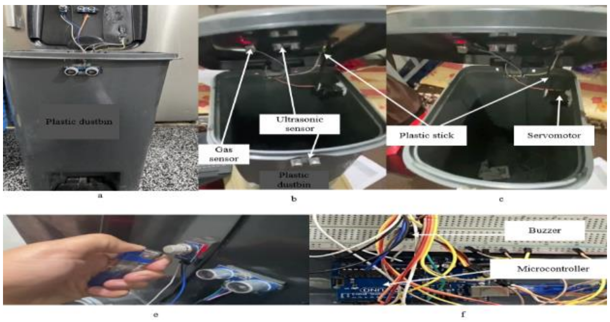

Fig. 6: A) The Whole Platform, B) Sensors Installation, C) Plastic Stick and Servomotor, E) Cigarette Lighter and Gas Sensor, F) Placement of Control Components.

4. Safety and Maintenance Considerations

The performance and longevity of the sensors included in the system can be significantly affected by environmental factors like humidity, dust, temperature variations, and exposure to sunlight or rain. For instance, moisture or condensation on the transmitter or receiver surface may cause ultrasonic sensors to lose precision, resulting in inaccurate readings or an inability to detect waste levels. Similarly, extended exposure to high humidity or volatile chemicals can cause calibration drift or damage to gas sensors, which impairs their capacity to accurately identify dangerous gases.

Additionally, if the servo motors that open the lid are not protected or rated for hard environments, they may not perform properly in dusty or high-humidity conditions. Furthermore, over time, dust buildup on sensor surfaces can reduce their functionality. Sensors and electronic components should be enclosed in sealed enclosures to improve system reliability and guarantee steady functioning in a range of environmental circumstances. Apply protective coatings that are resistant to damp and water to delicate surfaces. When deterioration in sensor performance is identified, incorporate a self-cleaning procedure or periodic maintenance alerts. To decrease the impact of a single sensor failure, use redundant or dual sensors.

By implementing these precautions, the system will last longer and be able to function well in both indoor and outdoor settings, particularly in areas with fluctuating climates like Iraq.

To ensure continuity and effectiveness, a simplified maintenance manual can be developed as shown in Table 5, which enhances awareness and reduces the possibility of sudden downtime.

Table 5: Continuity and Effectiveness

Task	Repetition	Procedures
Clean The Sensors (Gas/Ultrasonic)	weekly	Use a soft, dry cloth. Avoid strong chemicals.
Check The GSM Module's Operation	monthly	to ensure the successful reception and transmission of test messages.
Calibrate The Gas Sensor	every three months	using a known gas source or according to the manufacturer's instructions.
Check The Battery	monthly	to check the charge level and replace it if signs of weakness appear.
Container Body Inspection	Semi-annual	to ensure there are no cracks or mechanical damage to the lid or frame.
Full System Test	Monthly	Run the device in simulation mode and check all responses.

This research represents a good step toward applying Internet of Things (IoT) technologies in waste management. The design is based on sound scientific foundations and careful use of performance indicators. Despite the limited practical experience and some gaps in the presentation, the work is scalable and can be improved to become a more comprehensive and effective system in practice.

5. Conclusion

Waste management has grown in importance as an issue of study. Garbage bins are beneficial in reducing trash overflow in public spaces, businesses, and healthcare facilities. Therefore, waste monitoring technology improves the effectiveness of garbage collection. The experimental findings are applied using the calculation of the statistical parameters' sensitivity, specificity, and accuracy, which are around 93.333%, 93.333%, and 94.791% respectively, for two situations with two rounds. The ultrasonic sensor may be combined with other sensor types in the future to get readings with greater accuracy. However, because the procedure is new in Iraq, public knowledge should be established before it is widely utilized. Alternatively, components like sensors could be damaged by users' rough behavior.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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