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Smart Dustbin using ESP32 for Waste Management

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Abstract

This research aims to develop a smart bin equipped with advanced technologies to enhance household cleaning and waste management. The primary objective is to minimize manual intervention and inefficient cleaning processes. The proposed system design integrates real-time sensor data, autonomous operation, and modular eco-friendly components. The proposed smart dustbin is designed to manage waste by automating both the collection and disposal of household waste. Performance evaluation demonstrates effective dust detection, ensuring efficient cleaning with minimal manual intervention. The system's modular design facilitates scalability and potential integration of IoT and AI technologies for future improvements. By combining automation with sustainability, this smart dustbin addresses the challenges associated with waste management in smart homes.

Keywords: Dust Sensor, ESP32, Dust sensor, Ecosystem, Smart home Technology.

1. Introduction

In today's rapidly advancing technological world, one important issue that demands immediate attention is garbage management. Overflowing trash cans are a common problem, that makes it harder to create a clean, and healthy environment. Waste management is a global challenge faced by communities worldwide. The primary problem with conventional dustbins is that waste often spills over or is improperly disposed of around the bin, resulting in unhygienic surroundings [6.7].

This research aims to design a smart dustbin for home use, with the potential to incorporate advanced technologies for efficient citywide waste management in the future [8-10].

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The proposed system is designed to include advanced sensors to detect the dust and intimate the time of disposal. This helps avoid the overflowing of the dustbins and reminds us of timely disposal and sends alerts to clean the dustbin [11]. By integrating cleaning and waste disposal into a single automated system, the smart trash bin redefines the standards of home automation.

1.1 Objectives

The primary objective of this work is to develop a smart dustbin that integrates waste disposal systems, addressing the limitations of the traditional dustbins used at the home. The system is designed to enhance hygiene through contactless operation, ensure sustainability with eco-friendly waste management, and enable efficient cleaning by the proper integration of the sensors to detect the motion, the garbage level, and the bin maintenance.

2. Related Study

The Smart Waste Management System (SWMS) is a revolutionary waste management system that uses IoT technology, data analytics, and real-time monitoring to optimize waste collection routes and schedule maintenance. It uses sensors in waste bins to collect data, transmit it wirelessly to a central server, and offers a user-friendly interface for remote monitoring [1]. A Smart Dustbin System (SDS) [2] is proposed to improve hygiene in densely populated urban areas. Implemented with advances from deep learning, computer vision, and the Internet of Things, the SDS minimizes bin overload, lowers labor costs, and saves energy and time. Primary users include universities, malls, and high-rise buildings. This research [3] presents an IoT-based trash-checking system using an Arduino or Raspberry Pi board and an open IoT stage. The system uses an ultrasonic sensor to determine the depth of trash and the weight of the waste receptacle from the heap cell. The system communicates information through an LCD screen, Wi-Fi module, Thingspeak, and an open IoT discussion, allowing executives to track and plan waste disposal effectively. The Smart Dustbin research in [4] aims to improve waste management by detecting human hand movements and waste levels in a dustbin. The prototype uses Arduino, NODEMCU, Servo Motor, and Ultrasonic Sensors, with an application called Blynk for notification. The system can be used as a starting point for a Smart Waste Management System, allowing officials to clean or empty the dustbin based on notifications, reducing the need for societal calls for garbage trucks to collect waste. The study

in [5] aims to address the challenge of poor garbage management in cities worldwide by developing a GSM and GPS-enabled Smart Dustbin. It uses an Ultrasonic Sensor to prevent overflow and a Gas Sensor to detect bad odors, ensuring efficient and clean disposal.

The proposed system is designed based on the existing works to develop a contactless and minimal human intervention smart dustbin using the ESP32 and sensors to ensure a clean and safe environment.

3. System Overview

The proposed system integrates both hardware and software components to deliver a seamless and efficient waste management experience. The hardware and the software components are tabulated in the Table 1 below.

Table 1. Components Used.

Hardware Components	Software components
ESP32 Microcontroller	Arduino IDE
Ultrasonic Sensors (HCSR-04)	C++ for coding
Dust Sensors (PMS5003)	
Motorized Lid	
SIM800 GSM module	
Servo Motors	

3.1 Block Diagram

The block diagram depicted in Figure 1. illustrates the functional interconnections between various components of the smart dustbin system, illustrating the flow of information and operations. Each module is systematically arranged to perform a specific task, contributing to the overall functionality of the device [12].

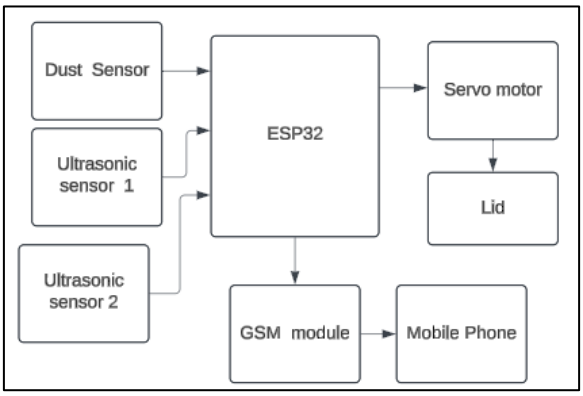

Figure 1. Block Diagram of the Smart Dustbin

The ESP32 microcontroller serves as the central processing unit and manages the communication with the dust and the ultrasonic sensor connected to it. It also manages the lid and the GSM module based on the data sensed from the sensors. The ultrasonic sensors detect the motion to open the lid when approached and monitor the level of the garbage. The dust sensor alerts the users if there's excessive dust buildup, indicating the bin or its surroundings need cleaning by monitoring the amount of dust or fine particles in the bin and its surroundings. The ESP32 responds to data from the dust sensor by sending a message to the user using the GSM SIM800 module. A battery with a solar charger ensures proper power management of the system. The Figure 2 below illustrates the work flow of the proposed.

3.2 Working

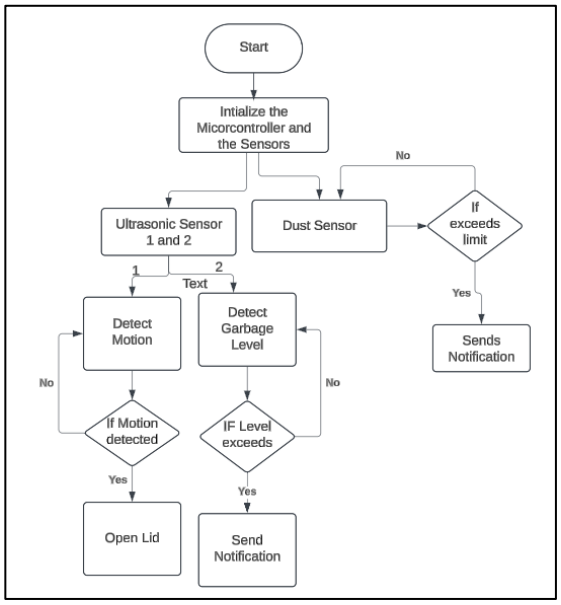

Figure 2. Flowchart of the Smart Dustbin

The system is initialized, and the ultrasonic sensors monitor for motion and the garbage level. If any motion is detected, the ESP32 triggers the lid to open and close and sends alerts for waste disposal through SMS to the user using the GSM SIM800 module if the garbage level exceeds the limit. Similarly, the dust sensors collect information on air quality and fine dust particles within the dustbin and its surroundings. If the dust level is high, the ESP32 and GSM module send a notification to alert the user to clean the bin. The notification is sent to the user's registered mobile number.

4. Implementation

The smart dustbin integrates various hardware components to enable autonomous waste management. This includes a dust detection sensor, motorized lid, and eco-friendly storage bags, all controlled by a microcontroller unit. The hardware setup is designed with a modular construction to simplify maintenance and enhance long-term reliability. Each component is selected for durability, energy efficiency, and optimal performance, allowing easy replacement or upgrading without disrupting the entire system. The software architecture includes a control algorithm programmed in C++ to manage the ESP32 microcontroller, coordinating inputs from sensors and directing actuator systems for autonomous functionality.

The C++ code is designed to manage the smart dustbin using the ESP32 microcontroller, HC-SR04 ultrasonic sensor, PMS5003 dust sensor, and the motorized lid. The hardware configurations for the sensors and the servo motor that controls the lid are defined, along with the distance threshold for the lid operation. The system is designed with two ultrasonic sensors one to detect user motion and automatically open the lid for waste disposal and the second one to monitor garbage levels to determine if the bin is full. The dust sensors monitor the air quality and fine dust particles. Whenever the garbage level or the dust level exceeds the threshold, the system opens the lid and sends an SMS alert using the GSM module to the registered user. The lid's operation is controlled by the servo motor and remains open for 1 second when the motion is detected or the bin is full. Further, the system's efficient operation is ensured by the battery and the solar charger.

5. Results

The results in Figure 3 illustrate the prototype developed for the proposed smart dustbin.

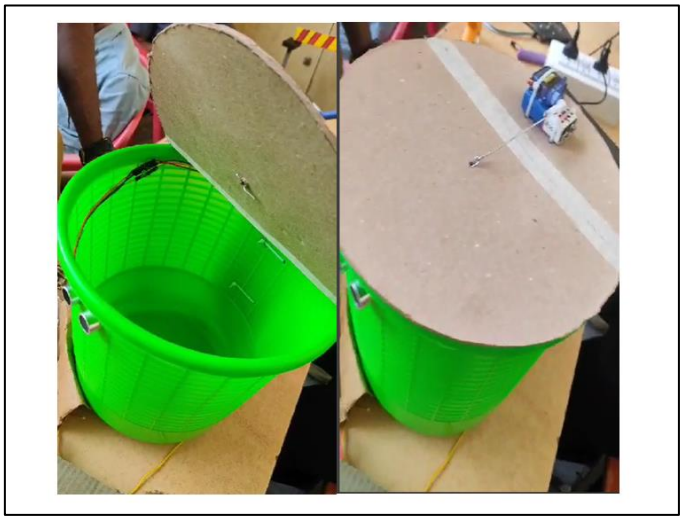

Figure 3. Prototype of the Smart Dustbin

The figure above illustrates the open and close operation of the lid, based on the motion detected using the ultrasonic sensors placed on the top edge of the bin. The results in Figure 4 depict the hardware setup of the ultrasonic sensor that is fixed below the lid to monitor the garbage level.

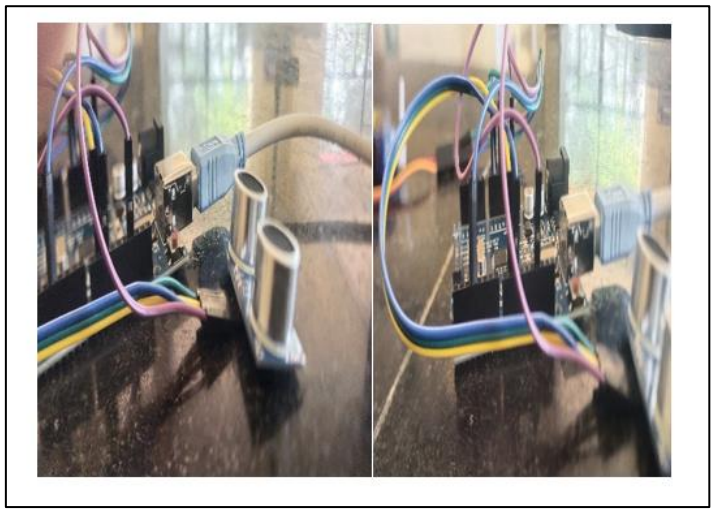

Figure 4. Ultrasonic Sensor for Garbage Level Monitoring

Figure.5 depicts the SMS alert forwarded to the users to notify the garbage level and the time to clean the dustbin.

Figure 5. Alert Notification

The prototype of the dustbin designed on a small scale can be developed into large sizes to support the condominiums and apartments, thereby ensuring a safe and hygienic environment.

6. Conclusion

The smart dustbin integrates innovative technologies to revolutionize waste management and home cleaning. Equipped with a dust sensor and ultrasonic sensor the system ensures precise and efficient contactless operation without human intervention. The integration of IoT capabilities allows users to monitor and take the necessary action when the bin is full or needs cleaning. For future enhancements, the device can be designed to incorporate advanced AI-driven algorithms for smarter decision-making, and identifying different types of waste for segregation. With potential applications in industrial and commercial sectors, the smart dustbin has a vast scope for scalability, making it a promising solution in the smart home and waste management ecosystem.

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